SUBCLASSIFICATION OF THE STATE HIGHWAY SYSTEM OF INDIANA BASED ON SYNTHESIS OF INTERCITY TRAVEL

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by

W. C. VODRAZKA

Joint Highway Research Project

PURDUE UNIVERSITY
LAFAYETTE INDIANA

Final Report

SUBCLASSIFICATION OF THE STATE HIGHWAY SYSTEM OF INDIANA
BASED ON SYNTHESIS OF INTERCITY TRAVEL

To: G. A. Leonards, Director
Joint Highway Research Project

February 15, 1968

File No: 3-3-38

From: H. L. Michael, Associate Director
Joint Highway Research Project

Project No: C-36-54 LL

The final report on Project C-36-54 LL approved by the Advisory Board on February 11, 1966 is attached. The report is titled "Subclassification of the State Highway System of Indiana Based on Synthesis of Intercity Travel" and it has been authored by Mr. Walter C. Vodrazka, Graduate Research Instructor on our staff, who performed the research under the direction of Professor H. L. Michael. Mr. Vodrazka also used this research report for his dissertation for the Ph.D. degree which will be awarded in June, 1968.

This research resulted in the selection of the important highways in Indiana for intercity travel. Those highways recommended for reconstruction to high standards of multilane design by 1972 and by 1982 are depicted. In addition, the State Highway System of Indiana was subclassified into four recommended subsystems.

The report is presented for the record and will complete research activity on Project C-36-54 LL.

Respectfully submitted,

Harold L. Michael

Harold L. Michael
Associate Director

HLM:mf

Copy:

F. L. Ashbaucher	R. H. Harrell	C. F. Scholer
W. L. Dolch	J. A. Havers	M. B. Scott
W. H. Goetz	V. E. Harvey	W. T. Spencer
W. L. Grecco	J. F. McLaughlin	H. R. J. Walsh
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M. E. Harr	R. D. Miles	E. J. Yoder
	J. C. Oppenlander	

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by

Walter C. Vodrazka
Graduate Research Instructor

Joint Highway Research Project

File No. 3-3-38

Project No. C-36-54 LL

School of Civil Engineering
Purdue University
Lafayette, Indiana

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ABSTRACT

Vodrazka, Walter Charles. Ph.D., Purdue University, June 1968. SUBCLASSIFICATION OF THE STATE HIGHWAY SYSTEM OF INDIANA BASED ON SYNTHESIS OF INTERCITY TRAVEL. Major Professor: Harold L. Michael.

This research report is concerned with the development of a procedure to select the important highways of the future in Indiana. The principal aims of the study were to subclassify the State Highway System of Indiana and to designate those highways which should be considered for reconstruction to freeway standards.

The method selected to achieve these aims was a statewide study of intercity travel desire designed to synthesize travel patterns on the State Highway System of Indiana as they would exist were the Interstate system of highways complete and fully operational. A completed, fully operational Interstate system was thus a major assumption of this study.

The Intercity Travel Desire Factor model chosen for this study was the product of the square roots of the populations of two interacting cities divided by the square of the minimum path distance between the cities. The resulting number for each city pair was assigned to each highway link making up the minimum path between the cities. A cumulative

total was maintained for each Indiana highway link in the network as each city pair was considered.

The final factor associated with each highway link was considered to be a measure of both the relative importance of the link and of the anticipated traffic volume on the link. More than 300,000 city interactions were calculated in determining the factors that eventually were used in achieving the study objectives.

The large size of the coded highway network necessitated the development of a tree type decomposition algorithm for minimum paths in large networks. In addition to enabling a solution of large networks, use of the algorithm resulted in a savings of computer time as well.

The adequacy of the Intercity Travel Desire Factor to synthesize travel was determined by a centroid analysis which consisted of a regression of the sum of the AADT's for all links entering a city on various measures of the sum of the factors for these same links. The model was accepted as adequate on the basis of an R^2 of 0.872 for data from 390 Indiana centroids.

A link analysis was then performed to develop a relationship between the link volume and the link factor. This was determined by a regression of the minimum AADT for a link on the factor associated with a link. The relationship developed, which expressed link volume as a function of the logarithm of the link factor, had an R^2 of 0.919.

This relationship coupled with other considerations such as system connectivity was used to subclassify the State Highway System of Indiana into four subsystems: the Principal, Primary, Secondary, and Collector State Highway Systems.

The Principal Highway System consisted of the presently designated Interstate Highway System and all highways which should be considered for reconstruction to freeway standards by 1982.

HIGHWAY CLASSIFICATION

Definition

Functional highway classification is defined as the grouping of roads and streets into classes, or systems, according to the character of service they will be expected to provide (3).*

Many other definitions of highway classification may be found ranging from the very simple such as highway classification is the process of grouping roads and streets according to the requirements of traffic (12) to more comprehensive statements of policy such as the following:

> The functional classification of public roads is the procedure by which portions of the road and street network of a State are grouped according to their predominant function or purpose in the overall system, and the responsibility for each grouping is determined and assigned to the level of government having the predominant interest in providing for their function. (17)

Some of the desirable characteristics of highway classification procedures and results are contained in the definitions employed by other agencies: the highways in each system or grouping must have similar functional usage (4, 7, 15, 16) and render comparable service (15); the number of

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* Numbers in parentheses refer to entries in the List of References.

systems into which roads are grouped should be minimal (16) but the size of each system should be manageable (14); and all systems are to be systematically interconnected throughout the areas they serve (7). The definitions of two agencies state only that classification is the process by which responsibility for each mile of road and street is assigned to one unit of government or other (1, 8).

This last definition is probably the best one, if a set of criteria on which the assignment of responsibility can be made is available, because the advantages and benefits derived from proper highway classfication accrue to the governmental units in their efforts to provide adequate highway facilities for the public.

Purpose and Necessity

Highway classification has been described as the basis, framework, foundation, and first requisite; as a device and tool; and as being indispensible. It makes possible, provides for, aids, enables, stimulates, promotes, improves, facilitates, decreases, increases, and has advantages and benefits.

The fundamental purpose of proper highway classification is that responsibility for a particular system be assigned to that jurisdiction most interested in the service the system provides.

Each jurisdiction has two responsibilities: to best serve the economy of the state and to best serve the public in their need for travel to places of employment, to haul livestock and farm produce, to deliver goods and mail, to reach tourist attractions, markets, shopping centers, as well as business, industrial, and social destinations.

There are many reasons why classification is necessary. Not all highways are alike either in respect to the service provided or in their desirable construction and maintenance standards. Available funds are limited. For example, the average expenditure per mile of rural highway in South Dakota in 1959 was $700 (18). Obviously little could be accomplished if funds were allocated equally per mile of road. Classification provides a means of determining the important routes upon which funds should be concentrated and the extent of the improvements thereon.

Classification is also necessary for the following reasons:

1. To formulate a long range program of development which is orderly, efficient, and economical (10, 12, 16, 18).

2. To provide for a systematic, interlocked arrangement of finance, management, construction, and maintenance (9).

3. To develop sound management programs (18).

4. To provide a firm, equitable fiscal structure (12, 18). The main problem here is that all levels of government want a larger share of the available funds (13).

5. To evaluate the relative importance of highways as a basis for highway improvement programs (19).

6. To provide for modern traffic requirements which demand a functional highway system (25).

Principles and Objectives

Three basic principles of highway classification are (15):

1. A road or street section can be placed in only one system.

2. The authority for a system can be vested in one government agency such as the state or in government agencies of the same level such as the several counties of a state.

3. Each government agency is completely responsible for the management, safety, improvement, operation, and maintenance of all roads in its jurisdiction.

The systems of roads resulting from the application of a classification technique must meet several objectives. Among these are:

1. Service. The needs of traffic must be served by each route through systems integrated for mutual support to provide service between all areas of the state (10, 18). Most travel is done over a road network or, more specifically, on a number of different roads such that few roads serve travel independently of others. A characteristic of modern travel is that all traffic tends naturally to the maximum

practicable use of higher type facilities. This is because of the greater time savings, comfort, convenience, and safety inherent in facilities providing reasonably direct routings and continuity of high standards over a relatively great distance (3). The channeling of traffic to roads of progressively higher standards and the willingness of the public to do so explains why some roads are more important than others and why classification is needed.

2. Stability. If a firm basis for planning and financing a highway system is to be available, it is necessary that the governmental unit have some assurance that changes in the system will be minimal and will be only those necessary to meet the changing travel and land use patterns of the state.

3. Economy. Those roads serving the most trip purposes for the most people should be among those considered for development to higher standards while those roads on which lower standards will suffice may also be identified. An important point here is that traffic volume indicates the standards of construction but is not the only indicator of functional importance (16).

4. Consistency. This implies that specific methods and procedures for classification should be uniformly applied throughout the state.

5. Efficiency. Efficient, effective management of the highway program by all involved jurisdictions must be

provided. The concept of jurisdictional responsibility is based on two principles (3):

a) The geographic limitations of a government unit must be recognized in measuring its ability to plan and administer effectively.

b) The response to public interest must be recognized. A problem of statewide interest generates action at the state level but a local problem generates only local action. An improperly classified road will thus generate agitation for action at the affected government level but no action at the jurisdictional level.

Advantages and Benefits

Most of the advantages and benefits of highway classification become reality only if the classification is properly done.

The principal advantages of classification are:

1. It provides for more efficient management with regard to administrative and financial responsibilities (2, 4, 5, 6, 7, 10, 11, 13, 14, 15, 16, 19, 25).

2. It facilitates the fiscal planning of long range highway development and improvement programs (2, 4, 5, 6, 7, 9, 11, 13, 14, 16, 25, 26).

3. It facilitates the planning of long range highway programs (2, 4, 5, 6, 7, 11, 14, 15, 26, 26).

4. It minimizes conflicts between government units since each mile of road is assigned to a specific jurisdiction (2, 5, 11, 16, 25).

5. It establishes a basis for the programming of improvements by priority or relative needs (2, 5, 7, 11, 14, 16, 26).

6. It provides a basis for the accumulation of cost data by which costs of the highway system may be charged to the appropriate beneficiaries, thus providing for more equitable financing (2, 6, 15, 16, 19).

7. It enables the development of reasonable minimum and design standards for each system (6, 9, 11, 14).

8. It enables the establishment of an efficient, specialized staff because all the roads of a particular system require the same degree of technical competence and ability in their design, maintenance, and operation (5, 9, 11, 15).

9. It provides for logical, integrated highway systems thus promoting the efficiency of the entire highway plant (5, 6, 11, 15, 25).

10. It enables the application and comparison of certain techniques, experience, and results both within systems and between the systems of various states (2, 16).

11. It provides for an easily understood picture of road needs and problems by the general public and by highway administrators (2, 11, 16).

12. It permits subclassification of any system for any desired purpose (15).

13. It provides a comparison datum by which road improvement programs and progress in providing an adequate system can be measured (2, 16).

14. It provides for the logical recording of highway traffic (16).

15. It facilitates the production of uniform motor vehicle accident statistics (2).

16. It enables a more complete and efficient maintenance program to be established (2, 11).

Classification Criteria

Some of the references studied listed a set of criteria for use in the selection of highway systems while in other references, the criteria are implied in the framework of a generalized procedure statement. Some studies provide criteria for the selection of state, county, and municipal systems and even subclassifications of each of these.

However, the same criteria may be applied to the selection of any system though not on the same scale. For instance, one often used criterion is the provision for service to points of traffic interest. This may be a city or major recreational area when considering the state system but a grain elevator for the county system and a shopping center for the municipal system.

Some of the criteria employed are:

1. Inter-center service. Population centers or urban places generate traffic in different ways and degrees. The importance of a place determines to a large extent the importance of roads connecting it to other places. Many classification procedures employ this concept in the actual selection of highway systems (8, 9, 10, 11, 12, 13, 16, 17, 19, 27). Some studies refer to this criterion as the connection of points of traffic interest (4, 7, 18).

2. Rural access or balanced area service. This is to ensure that all areas of the jurisdiction are reasonably served by highways. This is often done by trying to provide a particular class of highway, say a state highway, within a certain distance, say 5 or 6 miles, for most of the people living in a particular area. This criterion also includes the spacing of highways so that they are closer together in areas of high population density than in areas of low population density (5, 7, 9, 10, 15, 16, 17, 18).

3. Integrated, continuous systems. The most important highway system, i.e., the state system, must be made up of continuous highways such that an integrated, interconnected network covering the entire state is formed. Lesser systems, such as the county systems, need not be continuous but must be integrated and interconnected with the state system in order to fulfill their function as feeder roads and to provide an efficient traffic circulation system (5, 7, 10, 13, 16, 18, 27).

4. Traffic considerations. Occasionally, when a specific major system is being selected, some highways which cannot be considered for inclusion by other criteria have high traffic volumes or perhaps a considerable proportion of non-local traffic. Highways of this type should be considered for inclusion in the system (4, 5, 7, 9, 13, 16, 17, 18, 19).

5. Special road uses. Roads serving important interests should be considered for inclusion in a major system. Examples of important interests or uses are permanent mines, railheads, recreational areas, small towns, airports, isolated industries, national defense installations, and military bases (5, 7, 9, 13, 17, 18, 19).

6. Utilization of existing systems. This is important with respect to the selection of one of two alternate but similar routes. The route on a presently designated system may be developed and maintained to higher standards and should be selected (5, 7, 16, 17, 18).

7. Other criteria which have been mentioned in some studies include topography (5, 17), major post and school bus routes (4, 9, 16), service for the maximum number of trip routings with the least mileage (7, 18), adherence to legislatively imposed mileage limit controls (7, 18), provision of service to all counties and to all county seats (8, 10), and establishment of connections with major routes in adjacent states (9, 10, 13).

Elements of Classification

One of the more important questions to be answered is the number of systems needed. There are two basic considerations involved in answering this question:

1. Character of traffic service each system must provide.

2. Government units available to manage each system.

For classifications purposes, highway traffic consists of trips of three types: those of statewide interest; those of local rural interest; and those of local urban interest. Further analysis indicates that public highways must satisfy trip demands falling into three functional categories.

1. Longer, relatively high speed trips with only incidental land service.

2. Shorter, lower speed trips within a limited area with simultaneous land service.

3. Short, low speed trips where the emphasis is on land service.

These considerations give rise to three general systems in both rural and urban areas as shown below (18):

Rural	Urban
State Highways	State Highways
County Arterial Highways	Arterial Streets
Local Roads	Local Streets

The analogy of a highway system to house construction has been made in a South Dakota study (18). In building a house, the needs are a few main beams, some stringers, and many floor boards. Each element serves its purpose in distributing the imposed loads with the main beams having the greatest capacity to carry loads and the floor boards having the least. A house built of all main beams could do the job but at very high cost. All floor boards could not do the job.

A highway system is needed such that elements of increasing capacity to handle traffic are available to distribute traffic and to do so economically. Thus, a few main roads (state highways), a collector system (arterial highways or streets), and a general coverage system (local roads or streets) are needed.

Government units available to manage highway systems include the Federal, state, county, township, and municipal branches.

Federal classification efforts have been confined to statutes which have directed lesser government units to classify certain highway systems in order to be eligible for Federal-Aid. These efforts have resulted in the establishment of a nationwide system of Interstate highways, state primary and secondary systems, urban extensions, and even county arterial systems of roads eligible for Federal-Aid. However, none of these systems are managed by the Federal government.

The classification has been made by the governmental units involved but with the cooperation and approval of the

Federal government through the agency of the Bureau of Public Roads.

Federal efforts have resulted in the following benefits (14):

1. An integrated network of Interstate routes serving all states and a major intrastate system.

2. Greater uniformity in administrative practices.

3. Improvement of all major systems through allocation of funds.

4. Adequate standards of improvement and construction for each system.

5. Protection of the highway investment by requiring all participating jurisdictions to maintain all system mileage.

The individual states, however, have been the major unit of government to classify highway mileages. All states have selected a primary system under the terms of the 1921 Federal Aid Highway Act which limited the system to 7 per cent of total state mileage, among other provisions.

Some states also have designated state secondary systems and special purpose systems. Many states have other system subclassifications for administrative or other reasons.

The state of Washington, for instance, has subclassified the state highway system into five groups (22):

1. Interstate system.

2. Principal state systems. Includes highways connecting cities of 20,000 or more.

3. Major state system. Includes roads providing connections for cities of over 1000 or which serve major tourist, commercial, or industrial traffic movements.

4. Collector state system. Includes roads serving other populated areas.

5. Other state system.

The principal advantage of subclassification is that it provides a sound basis for the determination of improvement and construction priorities.

Need for Reclassification

The failure to properly classify roads underlies the basic highway problem confronting many states according to the Automotive Safety Foundation (1). Allocations of funds are sometimes based on political or financial expediency rather than on engineering techniques which measure the service a road provides.

Improper classification results in many inequities. Among these are: overtaxing the facilities, manpower, and funds of a government unit to provide satisfactorily for each mile of highway under its control; disproportionate distribution of funds; inequitable distribution of costs to the highway users; and misplaced responsibility by charging road officials to provide for services in which they have little or no interest.

Even if an entire road system were properly classified at one time, there are several reasons why this will not always be the case: changes in land use and population resulting in different patterns of travel; growth in population, vehicle ownership, and vehicle usage resulting in increased traffic and greater demand for more and better highways; the fast approaching completion of the Interstate system which is changing traffic patterns as motorists choose better, more direct routes; changes in economy and the development of industry and natural resources; and the construction of new recreational facilities such as parks and reservoirs.

Thus, a periodic review of highway system classification is needed to resolve existing inequities and to reestablish the benefits and advantages of proper highway classification.

Improper classification of a road, in either too high or too low a class, prevents the road from functioning efficiently. A local road may be quite important to the community it serves. It gets priority with respect to maintenance, repair, and snow removal. If this road were transferred to state control, its importance relative to other state roads places it near the end of the list for essential services. The result is disruption of traffic and land service and bitterness on the part of the community. The converse is equally true. A truly state road transferred to county control will not receive the attention it should. As a result, the motoring public does not get the transportation service it wants or needs and for which it has paid.

It is recognized that the completion of the Interstate highway system will have a significant effect on existing travel patterns not only in Indiana but throughout the Nation. Indeed, it has been estimated that the completed Interstate system, comprising slightly more than one per cent of the Nation's total road and street mileage, will carry 21 per cent of all traffic (29).

However, study of the proposed Interstate system shows that in many instances, Interstate routes closely parallel or coincide with existing major highways, such as I-70 and US-40 across Indiana. Much of the traffic on the existing route will simply shift over to the Interstate route.

Other cases of traffic diversion as well as traffic generation are expected because drivers will attempt to utilize the Interstate routes (and others built to similar standards) to the greatest extent possible. The reasons for this are many (29):

1. <u>Cost reduction</u>. Studies have shown in some cases that the cost of a freeway is balanced out by motorist's savings in less than 10 years.

2. <u>Safety</u>. Use of the Interstate System will save at least 5000 lives a year.

3. <u>Freedom in travel</u>. Long range highway travel for any purpose by any mode will be faster with greater comfort and less strain.

4. <u>Reduction of urban congestion</u>. Routes through and around larger cities and those which bypass the smaller cities will provide relief from the traffic congestion which today clogs many urban streets.

The concept of traffic diversion and generation is not new. It was pointed out in the historic "Road and Canal Report" by Albert Gallatin in 1808 when he wrote of the effects of the construction or improvement of routes thusly (31):

> ...The general gain is not confined to the difference between the expense of the transportation of those articles which had been formerly conveyed by that route, but many which were brought to market by other channels will then find a new and more advantageous direction; and those which on account of their distance or weight could not be transported in any manner whatsoever, will acquire a value, and become a clear addition to the national wealth.

It is often pointed out that there have been large increases in population, vehicles, and vehicle miles of travel in this country over the past several decades and that this growth is expected to continue. During the fifteen year period from 1948 to 1963, the number of vehicles and vehicle miles almost doubled while population and traffic-related fatalities each increased by about one third (32).

It is significant, perhaps, to note that road mileage during this same interval increased by a factor of about 1.04. This is in keeping with what probably is National policy in respect to highway transportation facilities as suggested by the following (29):

> ...most construction of 'new' roads actually is the replacement of betterment of existing facilities. A highway-improvement program therefore is not designed to achieve 'more' highways so much as it is to achieve 'better' or 'more adequate' ones.

Purpose of this Research

Two important points emerge from the discussion in the previous section:

1. Traffic patterns are expected to change so that some of the important state highways of today will not be too important in the future and vice versa.

2. Highway improvements, geared to provide for traffic requirements, should be concentrated on the existing roads which will be important state highways in the future.

The purpose of this research was to develop a method of selecting the important highways of the future in Indiana. A statewide study of intercity travel desires was selected as the means for achieving this purpose. The present State Highway System of Indiana as shown in Figure 1 was used in this analysis with the Interstate System assumed to be completed and fully operational.

The scope was limited in that a complete reclassification of the Indiana state highway system was not contemplated because only intercity travel of a non-local nature was considered. As the State highway system primarily serves intercity travel, however, only a small number of miles of State highway serving points of major interest (such as reservoirs and parks) was not included in the study.

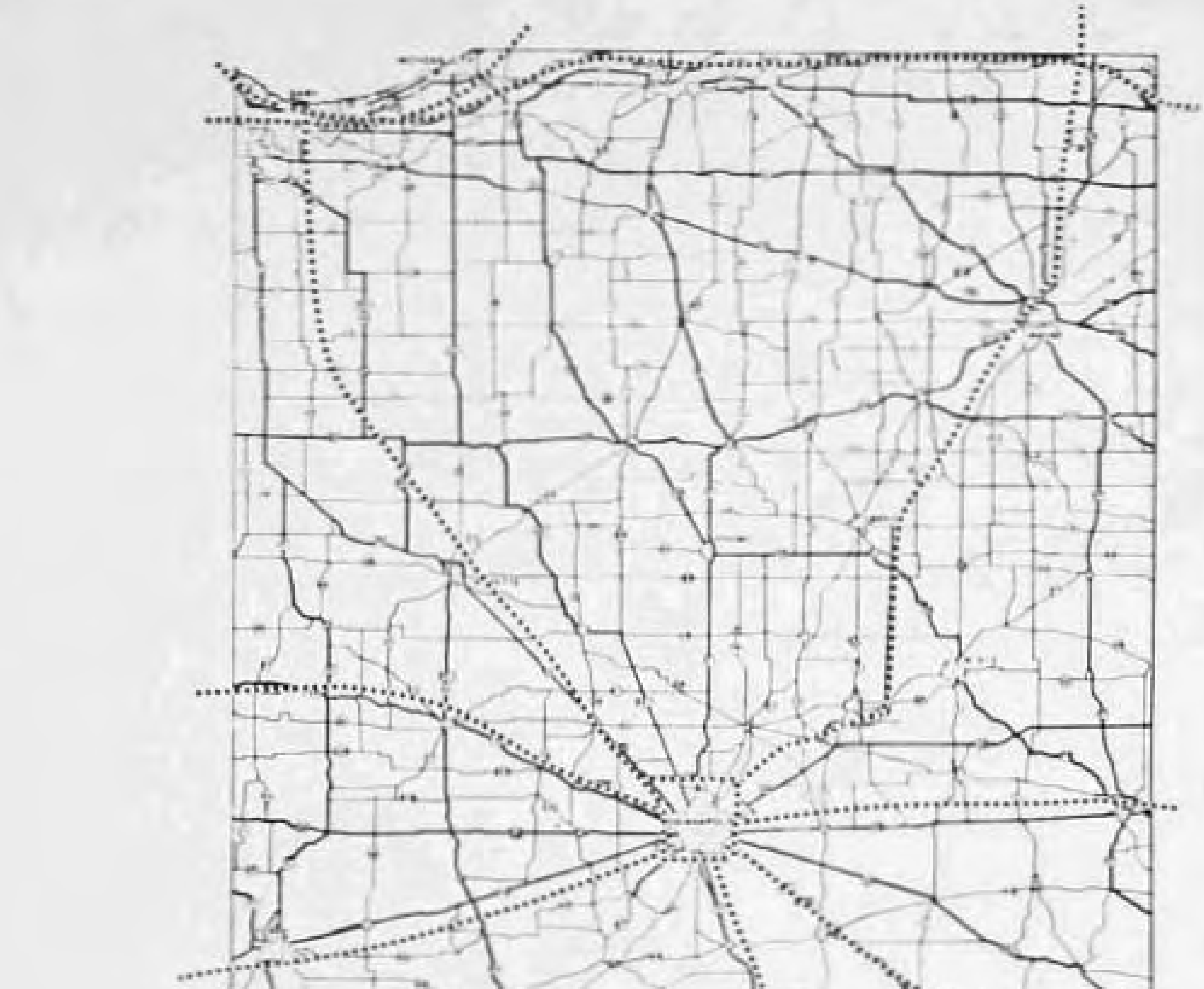

FIGURE I. THE STATE HIGHWAY SYSTEM OF INDIANA

The principal aims of this study were to subclassify those highways of primarily statewide interest in Indiana and to pinpoint those which should be considered for reconstruction to freeway standards.

HIGHWAY CLASSIFICATION IN INDIANA

Historical Development

Road building in Indiana during the immediate period following statehood in 1816 was generally confined to the National Pike or Cumberland Road and the Michigan Road as shown in Figure 2. Financing of these projects was derived from a five per cent tax imposed on the sale of Indiana public lands. Two per cent was to be retained by the Federal government for the construction of transportation facilities to and through Indiana and the remaining three per cent was to be used for internal improvements within Indiana (31).

The National Pike was built by the Federal government with the "2 per cent fund" while the Michigan Road was built by the State government with the "3 per cent fund." Neither of these roads were very good, being largely impassable much of the year, but they did open Indiana to large scale pioneer settlement.

Many other road and canal projects were initiated by the State during this period but the shortage of funds and piecemeal construction resulted in almost no improvement in the transportation problems of Indiana to 1836. Three conditions led Indiana to pass an internal improvements bill known as the System of 1836 (33):

FIGURE 2. HISTORIC INDIANA HIGHWAYS
(SOURCE : REFERENCE 31)

1. The Federal administration at this time was opposed to participation in internal improvements,

2. Several eastern states were successfully carrying out internal improvement programs of their own, and

3. Public disgust with the transportation problem had made it a political issue.

The bill provided that a loan of up to $10,000,000 be made for a period of 25 years at an interest rate of not over five per cent. The effects of this bill was a disaster of immense proportions to Indiana (33). Average state revenues at this time were $75,000 per year and the bill made no provision other than tolls for paying the $500,000 yearly interest due on the loan. Every road and canal project authorized by the bill was begun almost immediately, none was ever completed, and virtually no revenue was ever collected by the State. Work on the System stopped in 1839 and by 1844 the State debt was over $15,000,000.

This debt was settled later with great favor to the State but resulted in a complete loss of its credit. Thus, the new State Constitution of 1851 imposed strict limitations on the amount of indebtedness that could be incurred and prohibited the State from borrowing for public improvements (33).

This was not then an especially significant factor in the decline of road construction and maintenance because the railroads had captured virtually the entire market in the transport of passengers and freight. In fact, the period from 1850 to 1880 was known as the "Dark Ages of the Road" (31).

Legislation passed in 1877 authorized the several counties of Indiana to issue bonds for constructing and improving roads (34). The bonds were to be retired by assessments on the benefited property. Over the subsequent 40 years, many miles of gravel roads were built and maintained by the counties as a result of this legislation.

Several groups of cycling enthusiasts formed the League of American Wheelmen in 1880 and began a nationwide campaign for better roads, thus initiating the Good Roads Movement in many states (31). Their efforts resulted in the passage by several states of local road-aid laws, led by New Jersey in 1891, and the establishment of the Office of Road Inquiry by the U. S. Congress in 1893. Other Federal agencies, notably the Post Office and the Forest Service, developed an interest in good roads as well.

These developments coupled with the overwhelming public acceptance of the motor vehicle led to the passage of the Federal-Aid Road Act of 1916 which constituted the basic Federal highway law until the codification in 1958 of all highway statutes as Title 23 of the United States Code (35).

The Modern Era

The 1916 Federal-Aid Road Act was the first comprehensive step toward the development of a nationwide system of interstate highways. Among the provisions of the Act were included (31, 36):

1. Each State legislature must specifically assent to the terms of the Act and designate a State agency (highway department) to cooperate with the Federal government.

2. Projects contemplated by the State agency were to be approved and inspected by a designated Federal agency.

3. Each State must match the Federal appropriation with funds of its own.

4. The fund apportionment to each State was based on its area, population, and miles of rural mail delivery routes.

5. Federal-Aid was limited to construction of a designated primary highway system which was later limited to 7 per cent of the existing miles of road within each State by the Federal-Aid Highway Act of 1921.

As a result of this Act, the Indiana State Highway Commission was formed by the State legislature in 1917 (37). Because this legislation was immediately attacked in the courts, it was repealed and replaced by the 1919 Highway Act of Indiana (34).

The principal accomplishment under the terms of the 1917 Act was the designation of almost 900 miles of "main market highways" which connected the main market centers of Indiana. These roads are shown in Figure 3.

Under the terms of the 1919 Act, the State Highway Commission was charged with the laying out of a connected system of State highways which would reach every county seat

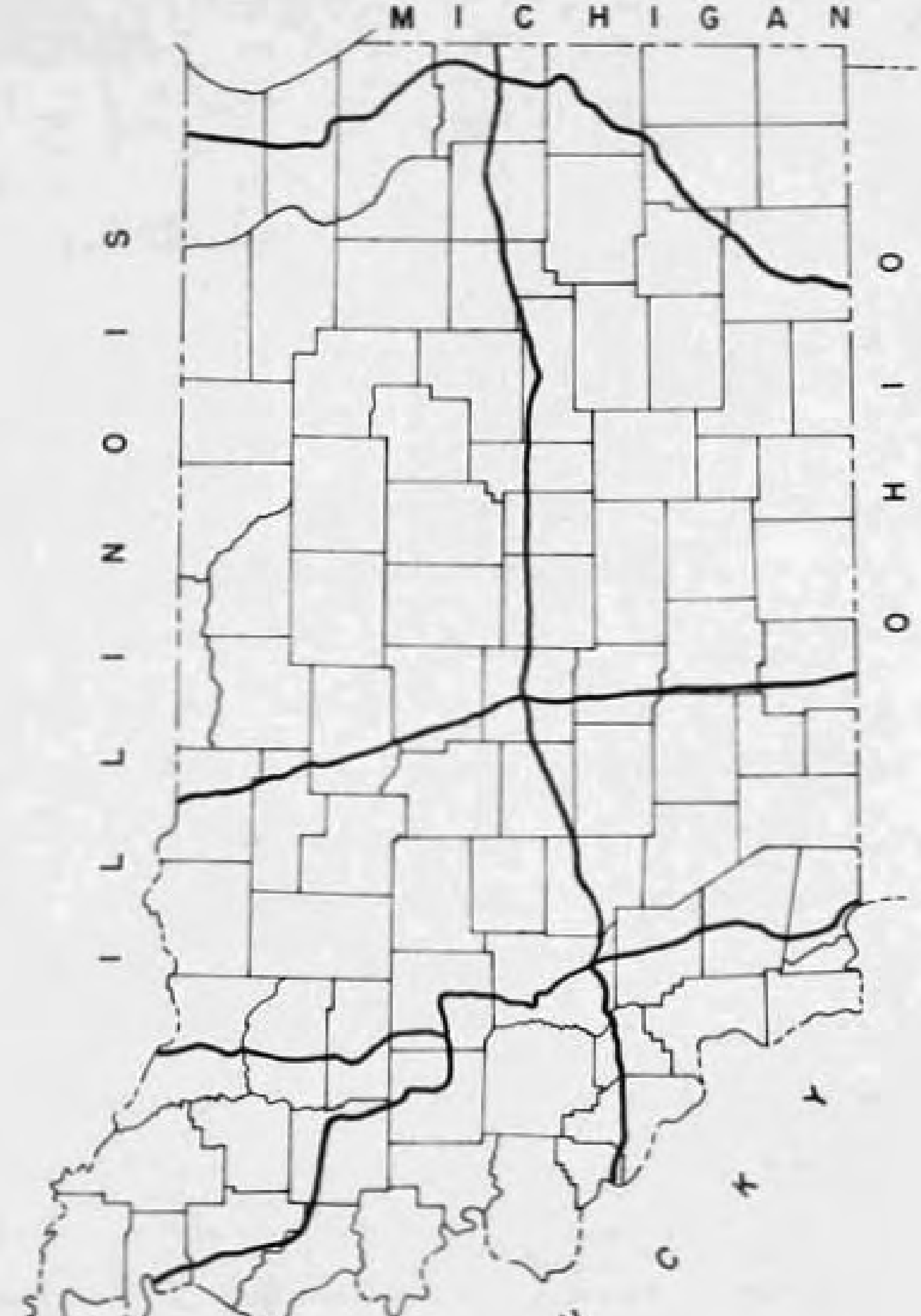

FIGURE 3. MAIN MARKET HIGHWAYS - 1917

(SOURCE : REFERENCE 37)

and each city of 5000 or more inhabitants. Thus, a 3200 mile State highway system, as shown in Figure 4, was approved and accepted in April, 1920 by the Commission for construction and maintenance.

This system amounted to about 5 per cent of Indiana's road miles with provision for an increase to about 10 per cent as funds became available to properly maintain the additional miles of road (38).

Throughout the succeeding years, the bulk of State highway legislation has had to do with the means of raising revenues and its subsequent apportionment to the State Highway Commission and to the counties and cities of the State.

The Federal government, however, passed legislation in 1944 authorizing Federal Aid for a system of secondary highways as well as urban extensions of primary and secondary highways. This legislation also provided for the selection of a national system of interstate highways limited to 40,000 miles (36). Other Federal and State legislation has also resulted in various subsystems of park, forest, and institutional roads. However, the bulk of Federal highway legislation, just as for Indiana, has been devoted to financing considerations.

Over the years, the Indiana State Highway Commission and the system of roads for which it is responsible have enjoyed substantial growth. The total length of the State highway system, which was limited to a maximum of 12,000

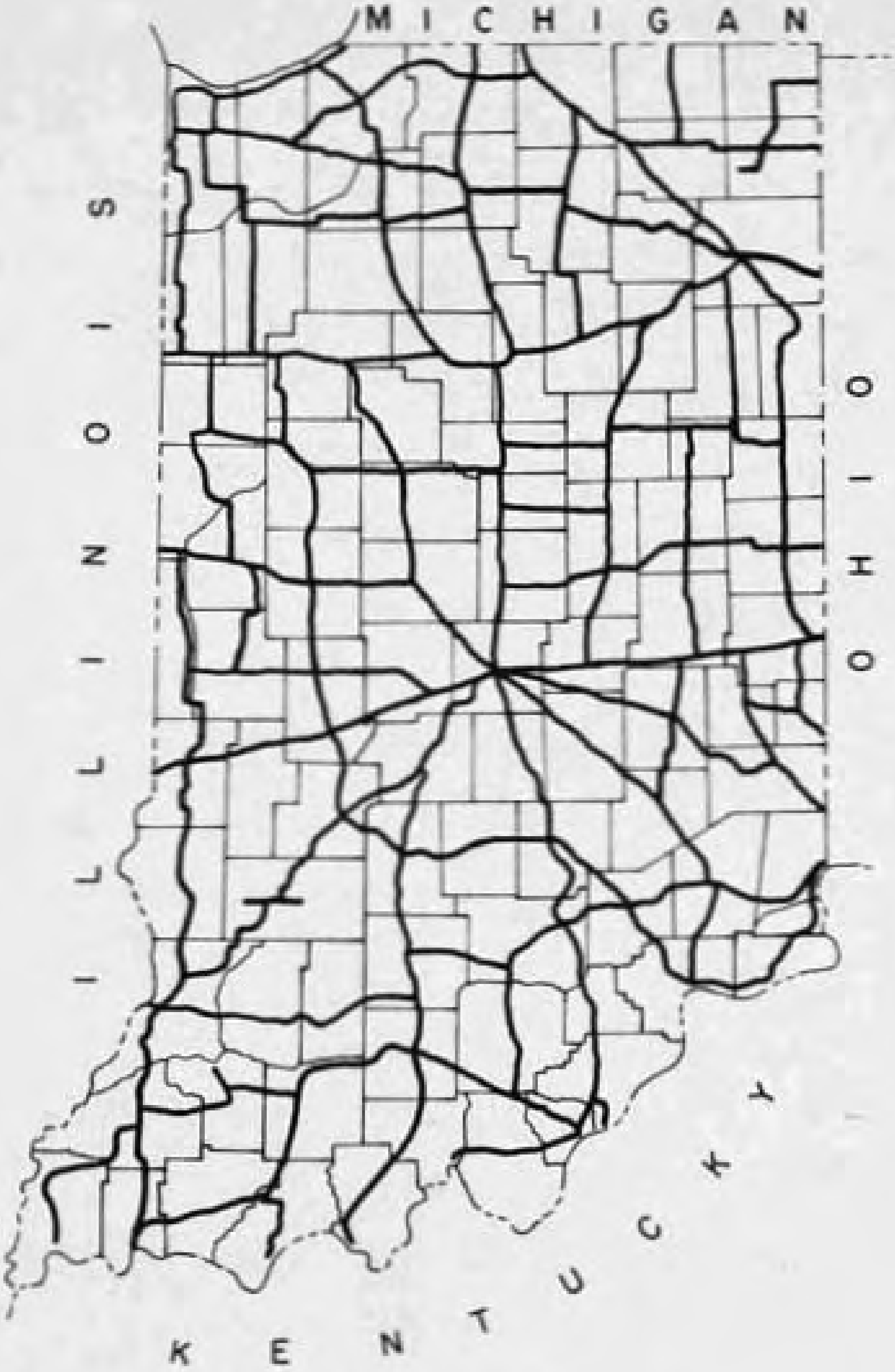

FIGURE 4. INDIANA STATE HIGHWAY SYSTEM - 1920

(SOURCE: REFERENCE 38)

miles by a 1937 Indiana Statute (34), reached approximately 11,500 miles in 1966 (39). About 4,170 miles of this total are on the Federal-Aid Primary System and 5,800 on the Federal-Aid Secondary System. In addition, there are 12,970 miles of Federal-Aid Secondary roads under county control. A total of 1,115 miles of Interstate highway are scheduled for Indiana with more than half open to traffic as of 1966.

Some idea of the growth of the highway system and the reasons for its development can be obtained by comparing some statistics for 1920 and 1965. The miles of road increased from 72,000 to 91,000, the State highway system mileage from 3,200 to 11,160, motor vehicle registrations from 0.33 million to 2.4 million, population from 2.9 million to 4.9 million, and receipts of the State Highway Commission from 4.14 million to $176.8 million with Federal-Aid from $0.49 million to $88.6 million (38,40).

The impact of Federal-Aid participation of 90 percent of the cost of the Interstate system can be readily visualized from two facts. Total Federal-Aid to Indiana in the 13 year span from 1941 to 1953 amounted to $69.3 million while Federal-Aid in 1965 alone amounted to $88.6 million of which $66.3 million was allocated for the Interstate system. Up until about 1960, Federal-Aid amounted to about 20 per cent of the Commission's receipts but since then, it has amounted to about 50 per cent (40).

Classification in Indiana

The Indiana State Highway Commission Law of 1919 charged the newly created Commission to lay out a system of State highways to reach each and every county seat and each and every city of over 5000 population and to provide connections to the main trunk highways of adjacent states such that a continuous system of improved highways would be formed. The system was to be constructed, reconstructed, repaired, and maintained by the Commission out of State highway funds (38).

This same Act also contained the specific assent of Indiana to the provisions of the 1916 Federal-Aid Road Act and all subsequent acts amendatory and supplementory thereto. The State Highway Commission was authorized to cooperate with the Federal government under any Federal law in any manner necessary to secure for Indiana the proportion of any Federal appropriation which may be made in the future (35).

The Indiana legislature has seen fit to give the Indiana State Highway Commission much of the authority with regard to highways but generally has not provided guidelines concerning legislative intent (25). For instance, the Commission has the authority to designate a State primary system but Indiana law includes few definitions, standards, or criteria for designating the system.

The Commission has the following authority (25):

1. It may add routes to the system if funds are available and if, in the opinion of the Commission, the route would make a desirable addition to the State highway system.

2. It may take over roads from other systems.

3. It may subclassify the State highway system into two or more classes and make any classification changes deemed necessary.

4. It may relocate existing highways to promote public safety and convenience or if the relocation will provide a more serviceable highway system than is possible under the existing location.

5. It may delete or abandon State highways as necessary.

6. It may designate municipal connecting links and add to, relocate, or delete them.

In some cases, the legislature has imposed some conditions on the Commission's authority but even here, the conditions do not hold if the Commission feels that changes are necessary and beneficial, i.e., in the public interest. The legal basis for much of the Commission's authority stems from the fact that a State highway is one so designated by the Commission (25).

Indiana statutes currently provide for only two rural highway systems: the State system and the several county systems. Each of the several counties has the authority to make changes in its system. County roads include all rural roads not designated in the State system. Generally, when any highway is deleted from the State system, it reverts to the counties but in some instances may revert to the original landowner (25).

CLASSIFICATION STUDIES IN OTHER STATES

Pennsylvania

Highway classification in Pennsylvania was accomplished on a county by county basis (20). The road system of a county was examined and if a road appeared to meet the definition of one of four proposed systems, it was so classified. Maps of adjoining counties were later compared and inconsistencies at county boundaries eliminated. The classifications were field checked and public hearings held in each county prior to legislative adoption of the systems.

Illinois

The method of classification proposed in Illinois was based on the concept that a highway's importance may be measured by its predominant usage. The assumption was then made that usage of a highway can be measured by the economic importance or traffic attraction of urban places connected by the highway and that highways connecting urban places of similar economic importance will have similar functional usage.

According to a Louisiana study (12), there are four basic principles which explain the ability of some urban places to attract traffic to a greater or lesser degree than other urban places. These principles are:

1. People make trips so that the larger the place, the greater the number of trips attracted or produced.

2. People make trips to see other people or to buy and/or sell. Therefore, urban places with more people, stores, markets, and other facilities will attract more trips than those with less such resources.

3. The larger an urban place, the farther people will come. This is because the greater population has more widely scattered personal relationships and also has greater and more specialized trade, service, cultural, and recreational resources, many of which are not available at home.

4. Trips make traffic such that highways connecting large trip producing and attracting urban places will generally carry the heaviest traffic.

In Illinois, the economic importance of an urban place was measured by determining its economic rating (15). Of the many factors characteristtic of an urban place, the following four were selected to establish the economic rating: population of the immediate trade area; bank resources of the immediate trade area; newspaper circulation of those published in the immediate trade area; and the assessed valuation of the trade center. A Michigan study, performed independently but at the same time, included the additional factor of retail sales in the trade center (28).

The rating was determined as follows. A factor, say newspaper circulation, was summed over every urban place included in the study to obtain a state total. The newspaper circulation of a particular city was divided by the state total to obtain a ratio. The ratios resulting from the consideration of all four factors were added and divided by four yielding the economic rating of each urban place.

Factor values for Chicago were not included so as not to distort the rating scheme and each factor was assumed to be of equal value in computing the rating.

The economic ratings were plotted on a uniform scale in decreasing order. Six apparent groupings were readily observed and urban places falling into each group were called metropolitan centers; regional centers; major market centers; market centers A; market centers B; and minor market centers.

Highways were then selected to connect those places of highest economic importance with each other and with similar places outside the State. Highways were next selected to connect places second in importance with each other and with those of greater importance. This process continued through the 6 place groups such that a basic highway system was formed. This method of ranking cities and selecting a basic highway system will be referred to later as the Illinois method.

The State primary system was composed of the Interstate system and all highways selected to interconnect cities through those identified as market center B. However, several other factors were employed to assure a balanced, integrated system. Some of these were: high volume roads performing a statewide service; roads connecting county seats not already connected; roads needed to provide a primary highway within 10 miles distance; roads needed to serve recreational facilities; and important roads in the Chicago area.

South Dakota

In a South Dakota study, cities were divided into 8 groups on the basis of population, retail sales, postal receipts, and livestock trading (18). Each factor was measured for the city and not the immediate trade area.

Aside from this, the Illinois method was used to rank the cities and to select a basic highway system. Supplementary routes to assure balanced, integrated service were selected by the following criteria: provision for system continuity and interconnection; accommodation of large traffic flows; provision for balanced area service; accommodation of special road uses; and the observance of legislatively imposed mileage limit controls.

Kentucky

A 1962 Kentucky study reported that all urban places of over 1000 inhabitants were ranked by population (19). However, all those of over 2500 were ranked by the Illinois method using the factors of population, manufacturing employment, retail sales, and bank assets for each individual city. Urban places with over 2500 persons were divided into

7 groups while those with populations between 1000 and 2500 were divided into 5 groups. Nearby cities in adjacent states were similarly grouped.

The cities were plotted one at a time on a map starting with the most important one. As each city was plotted, the most direct, feasible route to connect it to those already plotted was selected. All roads needed to connect group I cities were called group I arterials and so on through all 12 groups. A thirteenth group of roads was selected to account for routes carrying larger than average traffic and routes connecting large traffic generators such as recreational and military areas.

Manitoba

All cities of over 720 population in Manitoba were divided into 6 groups on the basis of population only (16). A basic highway system was then selected using the Illinois method.

Supplementary routes were selected to provide for rural access service and an integrated network.

Connecticut

All towns in Connecticut were divided into four groups by the Illinois method using the following factors: population, employment, grand levy, motor vehicle registration, and sales and use tax receipts (17).

Roads were then selected which served the predominant flow of traffic between any two towns. The roads needed to connect cities in groups I and II became the State primary system. The roads needed to connect the remaining cities became the State secondary system. A low mileage group of State special service roads was selected to provide access to recreational areas, institutions, and military installations.

The Connecticut study was somewhat unique in that it included a study of existing laws and developed legislation to implement the proposed system. The legislation became law and the process of road transfer from one jurisdiction to another was outlined and may be completed at this time. A special arbitration procedure for resolving differences was also established.

AASHO-NACO Guide

Part III of the AASHO-NACO Guide is a description of the technical procedure for classifying rural highways and supposedly indicated the extent to which a formalized procedure was then available (3). The procedure is divided into two main parts and a brief summary of each follows:

In laying out an arterial network, the following steps are required:

1. Rank population centers on a basis which indicates their relative radius of traffic attraction. Population alone is considered a sufficient ranking factor due generally to the incomplete availability of other information, especially for the smaller urban places.

2. Plot the centers graphically, in order of ranking, and divide them into 6 to 8 similar groups.

3. Repeat steps one and two for any out-of-state centers which judgment indicates have significant traffic attraction.

4. Plot each group of centers and their appropriate urban limits on a state map.

5. Connect the largest size centers by the most direct, logical routes. Connect the next largest centers and continue working down through the smaller centers. Good judgment is essential in determining which connections should be made and reference to a traffic flow map is helpful in reaching decisions.

6. Log the routes in the sequence of their selection.

7. Determine the smallest size centers to be connected by noting at which point miles of road are being added without a significant increase in the vehicle miles of travel served or by visually noting that relatively few long distance trips are being served.

8. Add other routes as required including:

   a) Service to other major traffic generators (recreational or military).

   b) Significant corridor movements.

   c) Service to all areas of the State.

   d) Additions needed for continuity.

9. Consider inclusion of alternate routes where one facility cannot handle all movement, where one facility is

a parkway from which commercial vehicles are excluded, or where two alternate routes are separated by a geographical barrier.

In laying out a collector network, the procedure must be generalized to an even greater degree since information available at this level is often not precise and seldom complete. Generally, it should be performed at the county level and information obtained on the following factors: location of other population centers not on the arterial system; location of heavier than average traffic flows; location of freeway interchanges and river crossings; location of important traffic generators; and rural population density and land use distribution throughout the county.

A collector system is then selected, which in conjunction with the arterial system, will most efficiently meet the highway needs of the county.

Use of this procedure generally results in an arterial system comprising from 7 to 10 per cent of rural mileage while the extent of the collector system ranges from 20 to 25 per cent of rural mileage.

Ontario

The Ontario Department of Highways in 1957 developed two classification techniques to aid in defining the function of each highway (24). These techniques were Intercenter Service and Rural Access Service.

Intercenter service is based on the concept that the importance of a highway may be measured by the total amount of service it provides to interconnect population centers. Accordingly, each city of over 3500 population was placed in one of 6 groups identified in decreasing order as M, A, B, C, D, and E.

External origin - and - destination surveys were used to determine the average number of daily through trips for each type of city connection. For example, M to M connections averaged 660 daily trips, M to A connections 620, and so on. The average numbers of daily trips were found to congregate at values of 600, 300, and 100. Point values of 6, 3, and 1 were assigned to highway connections between each city pair making up one of the three characteristics connections. Judgment was used to decide if a connection should be disregarded when the distance between the two cities was great.

The points assigned to each highway section were summed and this number used to classify highways. However, since Southern Ontario has 88 per cent of the population in 7 per cent of the area, different point range classification criteria were used in Southern and Northern Ontario. These are shown in the following table:

Highway Class	Point Range
Southern Ontartio	
Freeway	Over 20
Major Trunk	6 to 20
Minor Trunk	1 to 5
Northern Ontario	
Major Trunk	Over 3
Minor Trunk	1 to 3

A measure of rural access service was needed to ensure that persons living in rural areas had reasonable access to Trunk highways. The principle employed was that areas of similar population density should be similarly served.

Areas completely bounded by Trunk highways and, in some cases, by shorelines were called highway cells. Highway accessibility was measured as the distance in miles from the most remote point within the cell to the bounding highways. This distance, when combined with the cell's population density, provided a measure of under- or over-service to particular areas.

Detailed study then determined whether a route should be added or removed from the system such that the system would retain its continuous, integrated character.

Washington

The State of Washington's classification procedure was composed of two parts. The first was an analysis designed to yield an Index of State interest in highways. The main purpose of the Index was to indicate whether or not the road section could be considered of sufficient State interest to be on the State highway system (21).

The Index was a composite weighted average of the following six factors:

1. Intercity travel desire factor (ITDF). All cities of over 1000 population in Washington and within 20 miles of its borders were included in the study. A basic factor was first obtained for all possible city pairs by taking the square root of the product of the populations and dividing by the square of the distance between them by the most direct, feasible route. The basic factors assigned to a particular road section were summed, the result being called the intercity travel desire.

The assumption was then made that if the minimum average annual daily traffic (AAD) on a road section could be determined, it would be an adequate measure of through traffic with local influences essentially eliminated. If this assumption is correct, then the AAD of a road section should be highly correlated with its calculated intercity travel desire. A correlation coefficient of 0.93 was obtained from data at 65 locations on 7 cross-state routes. The correlation was performed with both variables in log form and since the b-coefficient was about 0.59, the relationship was non-linear.

The ITDF for each road section was calculated by multiplying the basic factor assigned to a road section by the length of the trip. When this had been done for all basic factors assigned to a road section, the sum of these modified factors was called the ITDF.

The multiplication by trip length was performed to take into account the fact that state interest increases with trip length.

2. Agricultural usage factor. This factor provided a measure of the intensity of road usage generated by agriculture in terms of the value of farm products in the area served by the road.

The area served by each road was first defined and the land assigned a productivity value as determined from data of the U. S. Agriculture Census. The land area in square miles was multiplied by the productivity value. The agricultural usage factor was this product divided by the length of the road.

3. Logging factor. Forest products are Washington's major industry and are especially dependent upon highway transportation inasmuch as over half the cost of log production is a transportation charge. The logging factor was computed as the number of million board feet of lumber hauled over a road section during a year.

4. Mining factor. Mining products in Washington are quite variable both in magnitude and value. Thus, it was decided to compute the mining factor as the total payroll of all mines served by a road section divided by the length of the road section.

5. Motor freight factor. This factor was taken as the average freight tonnage per day hauled over a specific route. It was designed to take into account long distance commercial trucking.

6. Recreation factor. Tourism is Washington's fourth largest industry and is the most dependent on a good highway system. A basic factor was computed by taking the square root of the product of the population of a city and the number of visitors to a major recreational area less 1500 divided by the straight line distance between the city and the area. Only cities with populations of over 2000 and recreational areas with over 1500 annual visitors were considered in the study.

The basic factor was assigned to the shortest, most feasible route and the recreation factor was taken as the sum of all basic factors assigned to a particular road section.

The Index of State interest was determined from the above six factors in two steps. It was first necessary to express each factor as a per cent because of the diversity in their units and magnitude. A mean maximum value was calculated for each factor as the arithmetic average of the highest values observed for the factor on any 100 miles of road in the State. Each factor was then divided by the mean maximum value for all road sections.

Each factor then had to be weighted to account for their unequal contribution to State interest. The existing

State system was used to provide the proper weights which, when finally selected, resulted in 91 per cent conformity to the existing system.

The Index was used to measure a route's eligibility for consideration as a State highway. A chart was prepared showing the cumulative miles with an Index equal to or higher than the Index being plotted. The Index at which the cumulative mile total equalled the present State system was 20 which was assumed to be the cutoff point for State interest.

A later study in 1962 employed the Illinois method to classify the State system (excluding the Interstate system) into four groups. All cities of over 1000 population were ranked by population and successively interconnected. All highways needed to interconnect cities of over 20,000 population were called Principal State highways while those needed to interconnect the remaining cities were called Major State highways.

Collector State highways were those needed to provide rural access service and service to recreational areas. Other State highways were essentially those which had a high enough Index to be included in the State system.

This classification technique was designed to provide a basis for priority programming of improvements.

New Mexico

The method of highway classification proposed in New Mexico consists of two steps similar to those employed in Washington. However, the method of applying them to classification was different (23).

The first step employed the Illinois method to select a basic highway system. The State was divided into immediate trade areas each served by a central place. Population, bank resources, newspaper circulation, and sales were used to rank cities. Five city groups known as regional centers, major market centers, market center A, market center B and minor market centers were selected.

A basic highway system was selected and each highway was classified by the type of city connection it provided as follows:

Primary	Regional-Regional Major -Major Regional-Major
Secondary A	Market- Market Regional-Market Major -Market
Secondary B	Minor -Minor Regional-Minor Market -Minor

This technique is called the Functional Approach and it results in what is called the minimum basic road system.

The second step involved the calculation of an Index for all roads to provide a measure of State interest. The factors considered in developing the numerical Index were:

intercity travel desire factor (including in-state and out-of-state phases), recreational factor (including in-state and out-of-state phases), agricultural factor, mining factor, and an oil and gas factor.

The criteria leading to the selection of these factors were:

1. Relative importance to the economy of the State.
2. Numerical nature of the pertinent data.
3. Availability and reliability of data.
4. Adaptability to a numerical index.
5. Flexibility of computed results.

The intercity travel desire factor was computed in essentially the same manner as in Washington but included an out-of-state phase to account for the significant use of New Mexico highways as corridors. The recreational factor was derived in two phases for the same reason. A special study was performed at a national monument and the recreational factor derived.

The agricultural, mining, and oil and gas factors were computed similarly to the Washington method but modified to reflect the type of data available in New Mexico.

The factors then were weighted and combined to give the numerical Index for each road section. The next step was to determine the Index cutoff points for each road classification so that all roads not already classified could be classified.

A synthesis of the Functional Approach was devised based upon the premise that the road-user services and relative importance implicit in the Functional Approach categories may be described explicitly by the relative standing of the numerical Indices for all roads in the minimum basic system. The resulting makeup of relative standings can then be extended to all highway sections not included in the minimum basic system by use of their numerical Indices.

A method using modal classes and arithmetic averages was devised to select the most representative numerical Index of each functional category. This data was fitted to a negative exponential curve and six functional classes were selected, the last three of which were Other 1, Other 2, and Other 3.

Comparisons of the numerical Indices of roads not classified by the Functional Approach with the Index limits of each of the six functional classes automatically provided the functional classification of these roads.

This method resulted in the recommendation of additions to, and deletions from, the existing system. However, before the recommendations could be implemented, they had to be considered in conjunction with the systems of adjacent states, jurisdictional responsibility, fund apportionment policy, the financial structure of the state, and laws already in effect or needed to implement the proposed system.

STUDY PROCEDURE

The principal aims of this study were to subclassify those highways of primarily statewide interest in Indiana and to pinpoint those which should be considered for reconstruction to freeway standards. The method selected was a statewide study of intercity travel desire.

This method was selected primarily because its use would result in the assignment of a numerical factor to each highway section in the State. The magnitude of the factor would be a measure of intercity travel desire and, hopefully, a measure of both the relative importance and anticipated traffic volume of each highway section. It was further envisioned that some function of the importance of a highway section and its overall condition as measured by a sufficiency rating could be used to establish a set of relative priorities for construction, reconstruction, and maintenance.

It was decided to calculate the Intercity Travel Desire Factors (ITDF) in the framework of a computer oriented mathematical model. It was reasoned that this method would be somewhat more objective in character than some of the methods described in the previous chapter. Even the least subjective methods described, those of Washington and New Mexico, depended on the researcher's judgment with respect to the most feasible intercity route. It was the intention in this study, however, to determine the most feasible intercity route based on the minimum path distance through the highway network.

Distance as used here and throughout the balance of this report when referring to minimum paths is not a true distance measure. This was due to the fact that highway sections built to less than Interstate standards were penalized by assuming a lower average speed.

The average speed on Interstate highways was taken as 60 MPH or one mile per minute. The length in miles of an Interstate section was thus numerically equal to the time in minutes required to traverse the section. The lengths of all other highway sections were multiplied by a factor to convert distance to time in minutes. The factor was computed as the ratio of 60 MPH over the assumed speed for the highway section.

Intercity Travel Desire Factor

The Intercity Travel Desire Factor used in this study is based on the gravity concept of human interaction. The basic postulate of the gravity concept is that the interaction between cities varies directly with some function of the populations of the two cities and inversely with some function of the distance between them. This may be expressed mathematically as:

$$ITDF_{ij} = f(P_i, P_j)/f(d_{ij})$$

where P_i and P_j are the populations of the two cities and d_{ij} is the distance between them.

A great deal of effort has been expended in developing the gravity concept of travel synthesis especially in the area of determining the functions to be used in the above expression. A detailed summary of much of the important work in this area may be found in a report by Tittemore (51).

The form of the expression used in this study was taken as:

$$ITDF_{ij} = (P_i P_j)^{1/2}/d_{ij}^{\;2}$$

This is the same form for the Intercity Travel Desire Factor as was used in the studies of Washington (21) and New Mexico (23) as reported in the previous chapter.

In the Washington study, several formulations of the travel desire factor were tried and each was correlated with the minimum annual average daily traffic on roads connecting population centers (52). The form of the factor listed above provided the best results, the correlation coefficient being 0.93 (21).

Several limitations regarding the use of the gravity concept have been pointed out (51). The principal one concerns the saturation of a city's travel desire. An upper limit exists on the number of trips that can be made in a given time period by each person. When this limit is reached, the relationship between travel desire, population, and distance is no longer valid. The exponent of distance has been shown to vary both as a function of distance and trip purpose. Some work has also been done in weighting the populations of cities to take differences in income and car registration, among others, into account.

Procedural Steps

The procedure followed in the performance of this research consisted of the following steps:

1. Coding of the highway network and the location of all cities to be used in measuring Intercity Travel Desire Factors.

2. Determination of the minimum path distance between each city pair. The large size of the network required the development of a tree type decomposition algorithm for finding the minimum paths in large networks.

3. Assignment of the computed travel desire factor between two cities to each link making up the minimum path between the two cities. The travel desire factor was computed as the square root of the product of the populations of the two cities divided by the square of the minimum path distance between them.

4. Determination of the adequacy of the calculated Intercity Travel Desire Factors to measure traffic by means of regression analysis. The dependent variable was the sum of the average daily traffic measurements on all roads going

in and out of a city. The independent variables were measures of the Intercity Travel Desire Factors.

5. Classification of the state highway system of Indiana into several functional classes. Highways recommended for reconstruction to freeway standards were also selected.

The highway network coded for this study consisted of the entire state highway system of Indiana, the major routes in the bordering states, and the nationwide system of Interstate highways. This network was quite large consisting of more than 1800 highway nodes and 2700 centroids with a total of over 6300 links.

This network was so large that it could not simultaneously be stored in the available computer. Thus, a decomposition algorithm capable of computing minimum paths in large networks had to be developed in order to carry out the objectives of this research. The development of the algorithm is presented in detail in the next chapter.

DEVELOPMENT OF A TREE TYPE DECOMPOSITION ALGORITHM FOR MINIMUM PATHS IN LARGE NETWORKS

Introduction

A highway system can be considered as a network consisting of a set of nodes N representing route intersections and links L_{ij} representing the portion of a route connecting n_i and n_j. The highway system can then be described by a set of links called a link table. Each link is described by its two end nodes and the associated link length d_{ij} which may be measured in terms of time, cost, distance, etc.

Some links may be directed, thus providing for only one way traffic while others may be undirected and provide for two way traffic. In the case of an undirected link, two link descriptions are necessary in the link table, one to indicate movement from n_i to n_j and the second, movement from n_j to n_i. It is not necessary that $d_{ij} = d_{ji}$. However, the network used in this study consisted entirely of undirected links for which $d_{ij} = d_{ji}$.

A path through the network leading from n_i to n_j is defined by a sequence of nodes each of which can be adjacent to only two links, i.e., an incoming and an outgoing link. The lengths of each link along the path may be summed so that a shortest path may be defined as the path whose total link lengths is a minimum.

Minimum path algorithms are available for determining the minimum paths between all node pairs. The algorithms may be divided into two classes, matrix and tree methods. Matrix methods simultaneously determine the shortest route between all node pairs in a network. In a paper by Mills (41), he states,

> The cascade method, which is the most elegant and efficient of the matrix methods, requires simultaneous storage for $2n^2$ variables, where n is the number of nodes in the network.

This amounts to 500,000 storage locations for a network of 500 nodes.

The cascade method is described in a paper by Farbey, Land, and Murchland (45). Mills also states that the time required for solution with the cascade method increases with the cube of the number of nodes (41). Because of the relatively large time and storage requirements for the solution of large networks, some recent work has been devoted both to shortening the calculations and the development of a decomposition algorithm including that of Mills (41) and Hu (46,47) among others.

Tree methods are used to find the shortest route from a source node to every other node, the process being repeated until all nodes have been used as sources. Tree methods require relatively less storage capacity than matrix methods but supposedly are more difficult to program and require a great amount of computation (41).

It was originally intended that the tree building algorithm used by the Bureau of Public Roads (43) be used in this study to determine the minimum paths between centroids. However, the coded network was so large that it could not simultaneously be stored in the computer. Thus, it was necessary to decompose the network in order to arrive at a solution.

The purpose of this section is to present the basic minimum path algorithm employing the tree method and then, the development of a decomposition algorithm to handle a large network by breaking it up into several manageable parts.

Basic Minimum Path Algorithm

The initial development of the tree building minimum path algorithm is generally attributed to E. F. Moore (42). In his paper, Moore presented four algorithms for finding the shortest path through a maze, the first three of which considered unit links while the fourth considered the imposition of a penalty such as time, cost, or distance on each link. This fourth algorithm was later modified and programmed as the basic tree building process used in the Traffic Assignment package as provided by the U. S. Bureau of Public Roads (43).

The essential operation of the algorithm is one of comparison. Consider any three nodes n_i, n_j, and n_k. The distance d_{ij} is considered minimum only if it is equal to or smaller than the sum $d_{ik} + d_{kj}$. The length of a one link path is compared with the length of a path through an intermediate node n_k and the original path is changed only if its length is the larger of the two distances (or costs, times, etc.). The process may then be extended to the comparison of path lengths where each path may be a sequence of several nodes.

Any network which has a finite number of nodes and links must also have a finite number of paths connecting any two nodes at least one of which is a minimum path. The problem is one of finding an efficient computational process which can find this minimum path directly rather than by trial and error.

Assume a network exists as shown in Figure 5-a and that the minimum path from a to b is desired. The first step was to find the link out of node a which had the smallest length and draw an arrow from node a to the node connected by this link. In this example, the arrow was drawn to node c and a '2' written alongside node c as shown in Figure 5-b.

The second step was to find the link out of a node already reached (either a or c) to a node not yet reached (either d, e, or h) such that the total distance back to node a was a minimum. At this point, an arrow was drawn from node c to node d and a '5' written alongside node d (where '5' is the sum of link lengths d_{ac} and d_{cd}). The written number is referred to as a label. This process

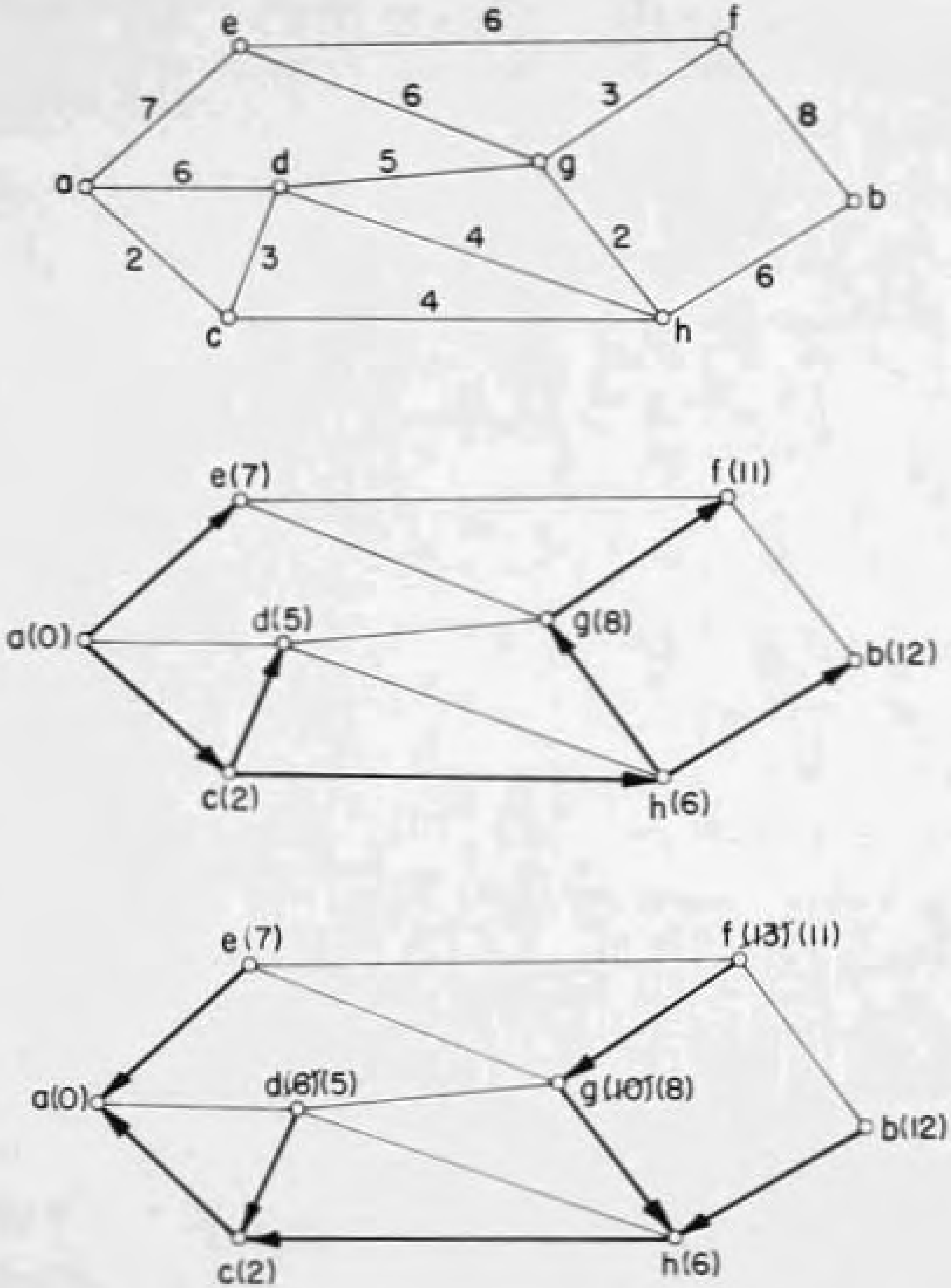

FIGURE 5 -a,-b,-c. A SMALL NETWORK ILLUSTRATING ALTERNATE MINIMUM PATH ALGORITHMS

continued until all nodes were reached and the minimum paths to all nodes were found as shown in Figure 5-b.

At any point in this process, the reached nodes may be considered as a set S where each node is labeled with a distance v_j, $j \epsilon S$ (j included in S) which is the minimum path distance back to the starting node. All unlabeled nodes make up the complement set $\bar{S}$. A node i is added to S and deleted from $\bar{S}$ provided that:*

$$v_i = \min_{j \epsilon S} (v_j + \min_{i \epsilon \bar{S}} d_{ji}) \qquad [1]$$

This process is time consuming and relatively inefficient for computer application with respect to the following alternate which is essentially that used by the Bureau of Public Roads (43). The first step of the alternate was to label all nodes that could be reached from the starting node with the associated link length. This differs from the first process in that the labeled distance may or may not be the minimum distance. The second step was to search the labeled nodes and find the node having the minimum label. In Figure 5-c, the labeled nodes at this point were c, d, and e and node c had the minimum label. Next, for each node that could be reached from c, the sums of the label on c and the associated link length were obtained.

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*Some of the preliminary detail and notation in this section is due to reference 44.

These sums were then compared with the labels on the newly reached nodes, in this instance d and h. If the node was labeled, the label was replaced only if the sum was less than the existing label, the case for node d in Figure 5-c. If the node was unlabeled, it was labeled with the sum, the case for node h.

The process then reverted to the second step to find the minimum label on the nodes, d, e, and h and continued until no further label changes could be made. The completed minimum path routings by this process are shown in Figure 5-c.

The arrows are reversed in Figure 5-c because the paths are traced back from each node to the starting node. In tracing the paths, the only restriction is that the difference in labels of two adjacent nodes must equal the link length.

In both methods, however, the paths and distances are identical and the paths from all nodes to the starting nodes were found.

In the second method it is convenient to label all nodes with an arbitrarily large number at the start except that the starting node is assigned a zero label. Then as the process continues, all nodes for which the labels change are placed in the S, all other nodes in the complement set $\bar{S}$.

The label v_i of a node, i, is changed and the node added to S provided that:

$$v_i > \min_{j \in S} v_j + d_{ji} \qquad [2]$$

where i can be a node already in S. The node, j, is removed from S when all nodes that can be reached from it have been checked as in [2] above. The process is completed when S is empty so that no further label changes are possible.

The operation indicated by [2] may be expressed in a slightly different form and as such is presented in the following theorem.

Theorem I. The minimum path distance to node i (not equal to j) must be equal to or less than the path distance by way of node j, i.e.:

$$v_i \leq v_j + d_{ji} \qquad [3]$$

and is equal to the minimum of all sums obtained by letting j vary over all nodes directly connected to i, i.e.:

$$v_i = \min_{i \neq j} (v_j + d_{ji}) \qquad [4]$$

The sequence of nodes defining the minimum path from node i to the starting node must include one and only one node directly linked to node i. Thus, if the minimum paths to all nodes j directly connected to node i are known, the minimum path for node i is defined by [4].

Suppose the minimum path between any two nodes, a and b, in a network is known. At any intermediate node j on the path, let v_{aj} be the minimum path distance to a and v_{bj}

the minimum path distance to b. If v_{ab} is the minimum path distance from a to b, then it must follow that:

$$v_{ab} = v_{aj} + v_{bj} \qquad [5]$$

If v_{ai} and v_{bi} are defined as the minimum path distances to nodes a and b respectively from any node i in the network, their sum would be greater than v_{ab} if the node i did not lie on the minimum path.

This leads to the following theorem:

Theorem II. If a set of nodes T is selected such that it is impossible to form any path from node a to node b without at least one node included in T, the minimum path from a to b is given by:

$$v_{ab} = \min_{j \in T} (v_{aj} + v_{bj}) \qquad [6]$$

Lemma I. If the minimum paths from all nodes (not including b) in a network to node a and the minimum paths from all nodes (not including a) in a network to node b are known, then the minimum path distance from a to b is given by:

$$v_{ab} = \min (v_{aj} + v_{bj}) \qquad [7]$$

where j varies over all nodes excluding a and b. Furthermore, the minimum path from a to b may be traced by connecting the sequence of nodes j for which [7] holds.

This must follow from [5] because node j can be any node on the minimum path sequence from a to b. This also serves to prove Theorem II since at least one node in T must be on the minimum path sequence of nodes. Lemma I may be generalized for any two nodes in the network provided that they are not connected by a direct link.

A Partitioned Network of Two Parts

Consider a network which has been separated along a set of border nodes T such that it is impossible to go from one side to the other without passing through one of the nodes in T. Let the nodes on either side of the border belong in sets A and B respectively.

In the network AT composed of the sets A and T, the minimum path distances from each node in T to all nodes in A may be determined. The same is true for all nodes in B when considering the network BT composed of node sets B and T.

Let w_{ja} be the minimum path distance within AT from node j in T to node a in A and w_{jb} the minimum path distance within BT from the node j in T to node b in B. Then, in a manner similar to Theorem II, the minimum path distance from a to b should be approximately:

$$v_{ab} \simeq \min_{j \in T} (w_{ja} + w_{jb}) \qquad [8]$$

as shown in Figure 6.

Equation [8], written as an equality, can be shown immediately to be false if the true minimum path from a to b is as shown by the solid line in Figure 7. The seeming

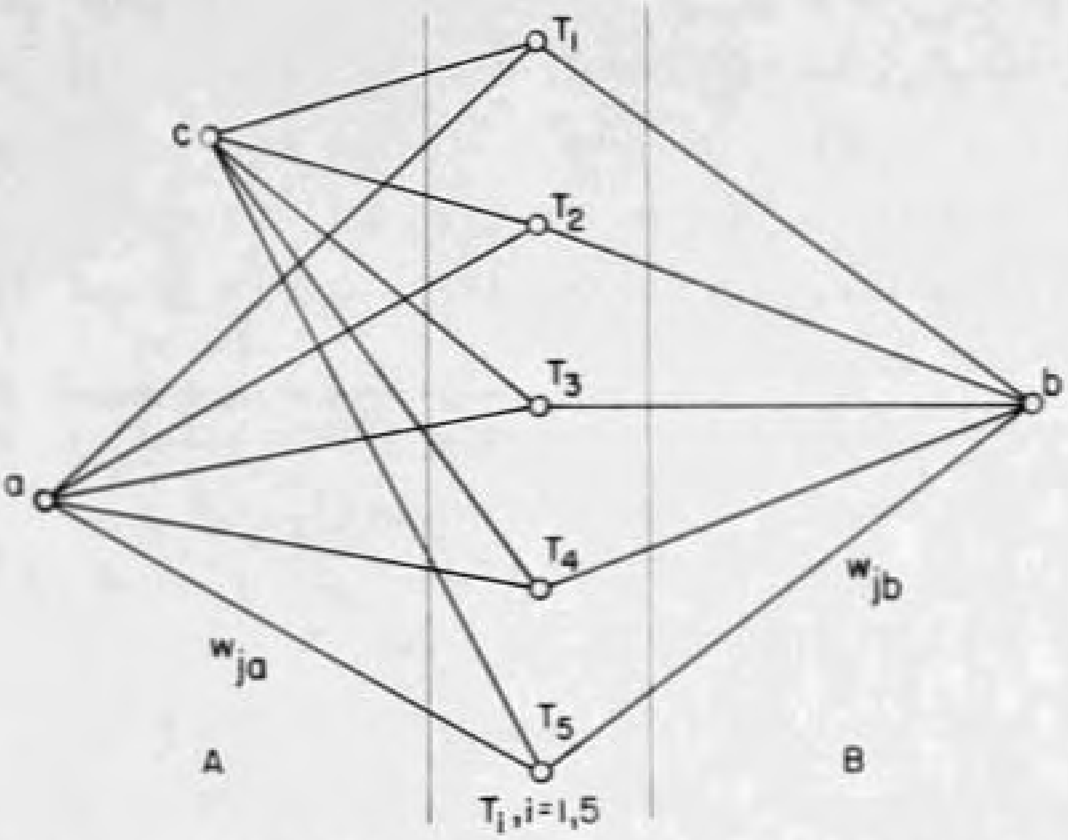


FIGURE 6. A PARTITIONED NETWORK OF TWO PARTS.

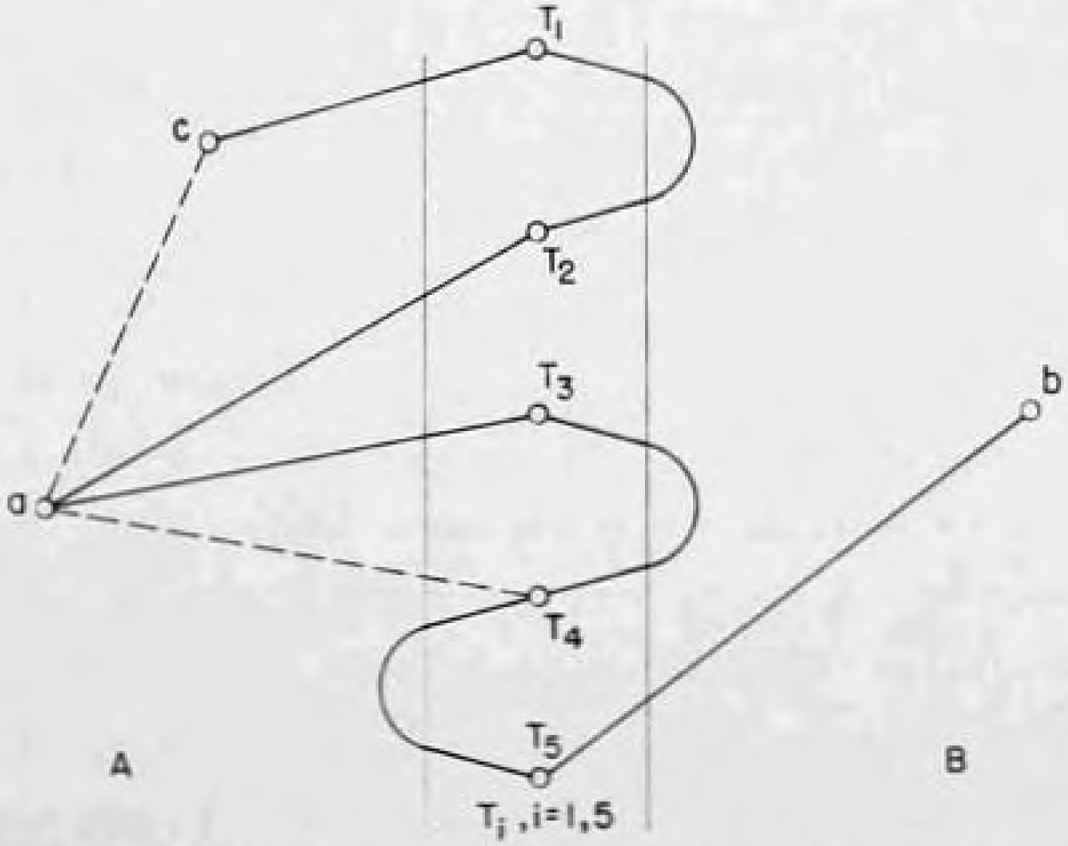


FIGURE 7. ALTERNATIVE PATHS THROUGH A PARTITIONED NETWORK.

inconsistency with Theorem II develops from a difference in definition of v_{ja} and w_{ja}. In Theorem II, v_{ja} was defined as the minimum path distance from node j in T to node a using the entire network. In [8], however, w_{ja} is defined similarly but only a part of the network is used. As a result, some nodes that lie along the minimum path node sequence may not be available so that only an apparent minimum path is found when less than the entire network is used.

In Figure 7, the path starts at b and goes to T_5 by way of nodes i in B, from T_5 to T_4 by way of nodes i in A, from T_4 to T_3 by way of nodes i in B, and from T_3 to node a by way of nodes i in A. However, if the true minimum path proceeds from b to T_5 to T_4 to a as shown in Figure 7, then equation [8] will give the true minimum path with j equal to 5 since the entire minimum path from T_5 to a is included in the node sets A and T. Thus, a problem arises when the true minimum path crosses the node set T at least three times when the origin and terminal nodes are on opposite sides of the node set T.

A similar problem arises when considering origin and terminal nodes on the same side of T such as nodes a and c of Figure 6. The minimum path from a to c may be obtained directly by the basic minimum path algorithm using node sets A and T provided that no portion of the true minimum path utilizes any of node set B. This is illustrated in Figure 7 where the path is from c to T_1 to T_2 to a. If the T_1 to T_2 portion of the path is contained entirely in a, no problem arises.

Thus, an algorithm devised to handle a partitioned network must be capable of handling both these situations.

The following theorem and its corollary will prove of value.

<u>Theorem III</u>. If the minimum path between nodes on opposite sides of T (such as nodes a and b) contains at most two nodes in T, the minimum path may be found directly from

$$v_{ab} = \min_{j \in T} (w_{ja} + w_{jb}) \qquad [9]$$

With three or more nodes in T, the minimum path may be found directly from [9] only if the entire portion of the path along the nodes in T lies on only one side of T.

<u>Corollary I</u>. If the minimum path between nodes on the same side of T (such as a and c) contains at most one node in T, the minimum path may be found by the basic minimum path algorithm using the appropriate node set and T. With two or more nodes in T, the basic minimum path algorithm will work only if the entire path is on the same side of T as the two nodes.

Decomposition Algorithm for A Partitioned Network of Two Parts

The proposed algorithm consists of several steps as outlined below.

1. Divide the network into two parts along a node set T such that it is impossible to pass from one part to the other without going through at least one node in T. The node sets on either side of T are A and B respectively.

2. Prepare the link tables for node sets A and T and for B and T. If adjacent nodes in T are directly connected, the link descriptions should be assigned to one but not both of the resulting link tables.

3. Use the basic minimum path algorithm with link table AT and calculate the minimum paths to all nodes in AT from all nodes in T. From these tree tables, generate a two dimensional array, w_{ta}, representing the distance from each node in T to all nodes in A. A second two-dimensional array, w_{tta}, representing the distance from each node in T to all nodes in T by way of nodes in AT, should be generated as well.

4. Repeat step 3 with link table BT, generating the distance arrays w_{tb} and w_{ttb}.

5. Use the basic minimum path algorithm with link table BT and calculate the minimum path tree table with a particular starting node in BT.

6. Introduce the w_{tta} array of step 3 at this point. For the first node i in T, sum the distance w_{ik} to the starting node k in BT (from the tree table of step 5) and the distance w_{ija} to node j in T (from the w_{tta} array). Compare this sum with w_{jk} (the label on j) and if:

$$w_{jk} > w_{ik} + w_{ija}$$

replace the label on j with the sum and place the node j in the set S. Continue this process over all nodes j in T. Repeat the entire step for all nodes i in T.

7. If the set S is empty, go to step 9. Otherwise, use the basic minimum path algorithm with the link table of step 5 to make any changes in labels on nodes in BT made necessary by label changes on nodes in T in step 6. Continue until S is empty. If, during the operations of this step, no label changes were made for any node in T, go to step 9.

8. Repeat steps 6 and 7 until conditions are such that transfer to step 9 is allowed.

9. Introduce the array w_{ta} from step 3. For the first node i in T, sum the distance w_{ik} from the starting node k to i (from the tree table) and the distance w_{in} from i to node n in A (from the w_{ta} array). Compare this sum with the label w_{kn} on n (initially set to an arbitrarily large value) and if:

$$w_{kn} > w_{ik} + w_{in}$$

replace the label on n with the sum. Continue this process over all nodes n in A. Repeat the entire step for all nodes i in T.

Discussion of the Algorithm

Due to the fact that the principal reason for using this algorithm is that of computer storage limitations, some consideration must be given to a computer oriented solution of the algorithm. One important point in this regard is that in large networks, the distance arrays generated in steps 3 and 4 may easily exceed the storage capacity of a computer by themselves.

The tree tables generated in steps 3 and 4 should be stored on tape so that the minimum paths may later be traced. The distance arrays must also be stored on tape and in such a way that the distances to all nodes may be read individually for each node i in T.

Step 6 of the algorithm is valid due to Theorem I which implies a procedure for comparing a path to a node with a path by way of another node. Each entry in the w_{tta} array may be considered as a direct connection between any two nodes in T so as to conform with the wording of Theorem I.

At the conclusion of step 5, the tree table contains the distances w_{jb} from each node in T to the starting node b as shown in the right hand portion of Figure 6. In step 6, the distance w_{4b} from T_4 to b (refer to Figure 6) is compared to the distance from T_4 to b by way of T_5 as shown in the right hand portion of Figure 7.

In step 7, the operations of the basic minimum path algorithm eventually makes a comparison of the distance from T_3 to b with the distance from T_3 to b by way of T_4

and T_5 as shown in Figure 7. Step 6 must then be repeated so that a comparison of say T_2 to b versus T_2 to b by way of T_3, T_4, and T_5 may be made. Eventually all possible comparisons will be made so that at the beginning of step 9, the true minimum paths from all nodes in BT to the starting node are in the tree table.

Prior to step 9, the tree table should be stored on tape and the next starting node read. Repeat steps 5 through 8 for each starting node.

The link table BT will not be needed to complete the tree table so that the storage space it requires is available for the operations of step 9.

The validity of step 9 is due to Theorem II which states that a minimum path between nodes on opposite sides of T cannot exist without at least one node in T. The minimum path between two nodes is defined as the minimum obtained by summing the respective distances from each of the two nodes to a node in T. At the conclusion of step 9, the minimum paths to all nodes in the network from the starting node have been found.

If all the nodes in BT have been used as starting nodes, then all paths from each node in BT to each node in A and vice versa are known. Hence, for a starting node in A it is necessary to complete only steps 5 through 8 to find the minimum paths to all other nodes in A using, however, the appropriate link table and distance array, i.e., AT and W_{ttb}.

Some additional considerations concern the tracing of the sequence of nodes corresponding to the minimum path. Theorem III and its corollary indicate that if more than one node in T is on the minimum path node sequence, problems arise in determining directly on which side of T the minimum path lies. These problems are overcome by the following procedure.

There should be no links in the link table BT used in step 3 which provide a direct connection between nodes in T. All links directly connecting nodes in T should be in the link table AT but with a dummy node providing the connection. Thus, for any direct connection, four link descriptions as opposed to two will be required. The dummy node is not considered as belonging to T.

These steps insure the direct determination of the side of T on which the path lies. Consider the tree table from step 9 for a starting node in BT. If a path trace contains no intermediate nodes between two nodes in T, that portion of the path includes only nodes from the set AT. If intermediate nodes do occur, then that portion of the path includes only nodes from the set BT.

For a starting node in A, the converse is true. The occurrence of intermediate nodes between any two nodes in T indicates that portion of the path includes only nodes from the set AT. The dummy nodes serve to provide the intermediate node when a direct connection is in the minimum path node sequence.

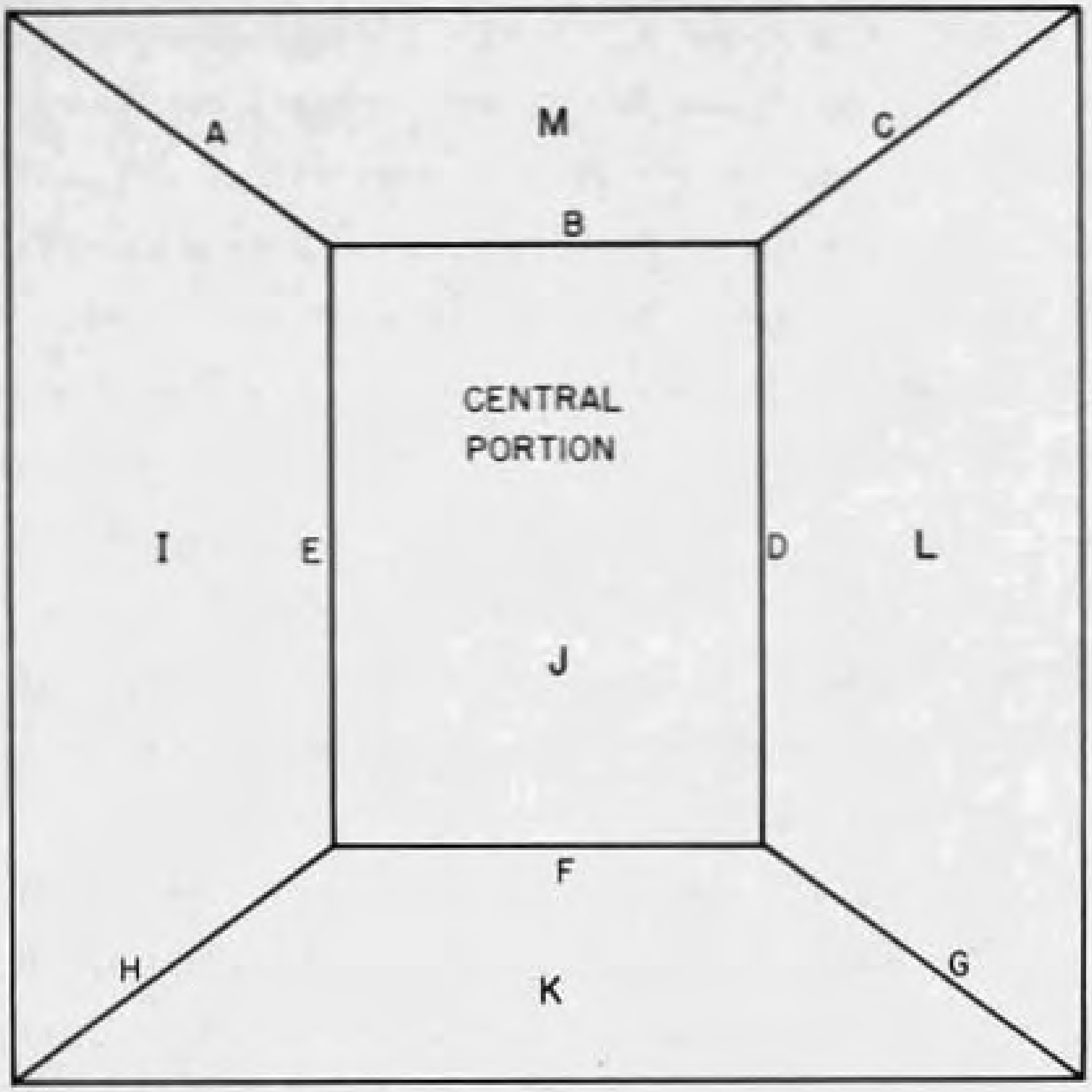
Extension to a Partitioned Network of Five Parts

Some networks are so large that they must be partitioned into more than two parts. Other networks, especially highway networks, lend themselves by geographical considerations to multi-partitionings.

One example is the road and street network of a large urban area. The central portion of the network has a high node density because of the closely spaced street grid pattern. However, as distance to the outlying areas increases, the node density becomes relatively low either because the roadway grid pattern is less closely spaced or because the detail required in the central area is not necessary.

Another example is that of a statewide highway network where the node-link configuration, although gross is nonetheless considerable. The network detail required in adjacent states is relatively sparse compared to that of the state in question.

In each of these examples, the central portion may be considered as a natural partitioning with several partitioned sectors emanating from it as shown in Figure 8. Here, the area is partitioned into five parts, each designated by its associated area node sets J, M, L, K, and I. The border node sets A, B, C, D, E, F, G, and H are each selected such that it is impossible to go from one part to another without passing through at least one of the border nodes separating the parts.



PARTITIONS - J,M,L,K,I.
BORDER NODE SETS - A,B,C,D,E,F,G,H

FIGURE 8. A PARTITIONED NETWORK OF FIVE PARTS

The magnitude of the computations involved in producing a tree table is extensive but depends to a large degree on the information desired and the assumptions one is willing to make. Generally, the nodes of a highway network fall into one of two classes, namely nodes which may be route intersections and centroids which may be any type of traffic generator such as an entire city or a residential zone in an urban area. Minimum paths are needed from a centroid to all other centroids but not to all nodes. This reduces considerably the size of the distance arrays needed in the performance of the algorithm.

The work is further reduced if only path traces which utilize nodes in the central portion are needed. An additional savings is made if one is willing to assume that the path between centroids within a partitioned area will never utilize the nodes of any adjacent area. This assumption will generally not introduce serious errors if the borders are relatively straight as in Figure 8 and if the centroids are not too close to a common border.

At any rate, the algorithm presented below outlines the procedure for the determination of the minimum paths from a starting node to all other nodes in the entire network. It may then be modified to suit the needs of the prospective user.

Decomposition Algorithm for A Partitioned Network of Five Parts

The decomposition algorithm as outlined here for five parts can be modified for n parts. It is presented in the context of a five part partitioning because it was in this form that the author solved the Indiana statewide network which is presented in the next chapter.

1. Divide the network into five parts designated as area node sets J, M, L, K, and I. Select the border node sets A, B, C, D, E, F, G, and H such that it is impossible to pass from one part to another without going through at least one node included in the border set separating the two parts.

2. Prepare the link tables JBDFE, MABC, LCDG, KGFH, and IHEA using the associated node sets in each case. All links furnishing a direct connection between nodes in any of the border sets should be broken by a dummy node. All links of this type along any border set should be placed in only one of the link tables adjacent to the border but none should be placed in link table JBDFE.

3. Use the basic minimum path algorithm to calculate the tree tables from all border nodes and then generate the distance arrays needed. The required distance arrays and the link tables used to obtain them are listed in Table 1. The distance array w_{bd} represents the distance from each node in B to all nodes in D while the array w_{bbj} represents the distance from each node in B to all nodes in B by way of

Table 1. Required Distance Arrays.

Link Table	Distance Arrays*
JBDFE	bd, bf, be, df, de, fe bbj, ddj, ffj, eej bj, dj, fj, ej
MABC	ab, ac, bc aam, bbm, ccm am, bm, cm
LCDG	cd, cg, dg ccl, ddl, ggl cl, dl, gl
KGFH	gf, gh, fh ggk, ffk, hhk gk, fk, hk
IHEA	he, ha, ea hhi, eei, aai hi, ei, ai

*Distance arrays listed in following order:
Line 1-Border node to border node
Line 2-Border node within border node
Line 3-Border node to node

nodes in JBDFE. In the case of border node to border node distance arrays such as w_{bd}, the reverse array w_{db} is also needed. These arrays are identical in regard to individual distances between any two nodes. The transpose of the w_{bd} array is identically the w_{db} array.

4. Use the basic minimum path algorithm with link table JBDFE and calculate the minimum path tree table with a particular starting node in J.

5. Introduce the w_{ba} array of step 3 at this point. For the first node i in B, sum the distance w_{ik} to the starting node k in J (from the tree table of step 4) and the distance w_{ij} to node j in A (from the w_{ba} array). Compare this sum with w_{jk} (the label on j) and if:

$$w_{jk} > w_{ik} + w_{ij}$$

replace the label on j with the sum. The initial label on each of the nodes of border sets A, C, G, and H, none of which were reached by the tree table of step 4, is set to some arbitrarily large value. Continue this process over all nodes j in A for all nodes i in B. Repeat this entire step for each of the 36 distance arrays listed in their calling sequence in Table 2 for a node in set J. However, if the label for a node in a border set adjacent to area J, i.e., border sets B, D, E, or F, is changed during the operations of this step, that node is placed in the set S.

Table 2. Sequence of Distance Arrays.

Node in Set J	Node in Set MABC	Node in Set LCDG	Node in Set KGFH	Node in Set IHEA
ba	bd	db	fd	ef
bc	cd	cb	gd	hf
dc	be	df	fe	eb
dg	ae	gf	he	ab
fg	bf	de	fb	ed
fh	df	fe	db	fd
eh	ef	be	eb	bd
ea	ed	bf	ed	bf
ac	de	fb	de	fb
ca	cg	gh	gc	hg
cg	dg	fh	dc	fg
gc	fg	eh	bc	dg
gh	ah	ca	ha	ac
hg	eh	ba	ea	bc
ha	fh	ea	ba	dc
ah	db	bd	df	fe
ab	dc	bc	dg	fh
cb	eb	fd	ef	be
cd	ea	fg	eh	da
gd	fb	ed	bf	de
gf	fd	ef	bd	bf
hf	fe	eb	be	db
he	gc	hg	cd	gh
ae	gd	hf	cd	gf
bbm	gf	he	cb	gd
bbl	ha	ac	ah	ca
ffk	he	ab	ae	cb
aam	hg	ah	ac	gc
ccm	gh	ha	ca	cg
ccl	aai	ccm	gcl	aam
ggl	bbj	ddj	ffj	eej
ggk	ccl	ggk	hhi	hhk
hhk	ddl	ffk	ddl	ffk
hhi	ddj	ffj	ddj	ffj
aai	eei	bbm	eei	bbm
	eej	bbi	eej	bbj
	ffk	eei	bbm	ddl
	ffj	eej	bbj	ddj
	ggk	hhi	ccm	ggk
	ggl	hhk	ccl	ggl
	hhk	aai	aam	ccm
	hhi	aam	aal	ccl

6. If the set S is empty, go to step 7. Otherwise, use the basic minimum path algorithm with the link table of step 4 to make any changes in labels on nodes in JBDFE made necessary by label changes on nodes in B, D, F, or E in step 5.

7. Repeat step 5, and step 6 if necessary, until such time that not a single label change is made during the entire operation of step 5.

8. Introduce the border node to node distance arrays in any desired sequence such as: am, bm, cm, cl, dl, gl, gk, fk, hk, hi, ei, and ai. Consider the w_{am} distance array. For the first node i in A, sum the distance w_{ik} from the starting node k to i (from the tree table) and the distance w_{in} from i to node n in M (from the w_{am} array). Compare this sum with the label w_{kn} on n and if:

$$w_{kn} > w_{ik} + w_{in}$$

replace the label on n with the sum. Continue this process over all nodes n in M for all nodes i in A. Repeat the entire step for each of the remaining 11 border node to node distance arrays.

Discussion of the Algorithm

Most of the remarks made earlier in the discussion of the decomposition algorithm for a network of two parts apply here as well.

All of the tree tables calculated in step 3 must be stored on tape if it is necessary later to trace the minimum paths. The distance arrays must also be stored on tape and perhaps card punched which will facilitate the formation of any desired sequence.

The reverse or transpose arrays need not be stored separately. This is due to the fact that a subscripted element of the transpose array is identical to the element in the original array with the subscripts in reverse order, i.e.,

$$w_{ij}^{T} = w_{ji}$$

Thus, whenever it is necessary to use a reverse array, the original array may be used with the subscript order reversed.

A feature of the algorithm is that the true minimum paths to all border nodes has been accomplished with the conclusion of step 7.

The basic method employed in achieving this result involves giving each and every border node the opportunity to be the suceeding node in a minimum path node sequence to the starting node. For instance in step 5 when the w_{ba} array is introduced, each node in B is tested to determine which will provide the path linkage from a node in A to the starting node. As a matter of fact, every node that can provide the path linkage for a node in A is tested including nodes in C, E, H, and A as well as B.

This procedure, the validity of which is based on Theorem I, is continued until eventually each node in A has been tested to determine if it will provide a path linkage to the starting node from nodes in B, C, E and H.

Because of the fact that each border node not reached in the tree table of step 4 was given an arbitrarily large label, a node not yet reached can never provide a path linkage for another node. If the large label was 10,000, then the comparison made in step 5 will be:

$$w_{jk} > 10{,}000 + w_{ij}$$

which will never allow a label change on the node j.

For this reason, the distance array sequences shown in Table 2 need not be strictly adhered to. The sequences shown merely provide that a node be reached before it is tested and that nodes are tested in some logical order so that the number of times step 5 must be repeated is kept to a minimum. However, any sequence used will eventually provide the same final result.

The reasons that step 5 must be repeated until no label changes are made can be visualized in Figure 9. Here a portion of the network at some stage of solution is shown. The path from nodes in H, F, and D has been established. If the gf distance array is now introduced and the label on a node in F changes so that the path now proceeds from the node in F to one in G, the label on the node in H is in error though the path node sequence may still be correct. The only way to correct the label is to again introduce the fh distance array by repeating step 5.

The border node within border node distance arrays such as ffk are last in the sequences of Table 2 for the reason illustrated in Figure 10. If w_{ffk} is introduced first and then w_{fh} , the path from points 1 to 3 will be as shown by the solid line. However, if w_{fh} is introduced first, the path will proceed from points 1 to 3 as shown by the dotted line. The paths in both cases are identical but in the latter, the path trace procedure is somewhat simplified. For similar reasons, it may be desirable to introduce the border node to node distance arrays of step 8 prior to the border node within border node distance arrays. In some cases, however, this may prove impractical due to computer storage requirements.

The path trace procedure required here is somewhat more complicated than that described for a two part network. In that case, the presence or absence of intermediate nodes between two border nodes indicated on which side of the border the path lay. In this case, that procedure will work only when the border nodes are part of a border adjacent to the area in which the starting node is included.

If the path trace shows two consecutive nodes from a another border set, say H, then the side of the border on which the path lies is determined by comparing the difference in labels of the two nodes in the tree table with their entries in the hhk and hhi distance arrays. The smaller of these entries must equal the difference in labels. If

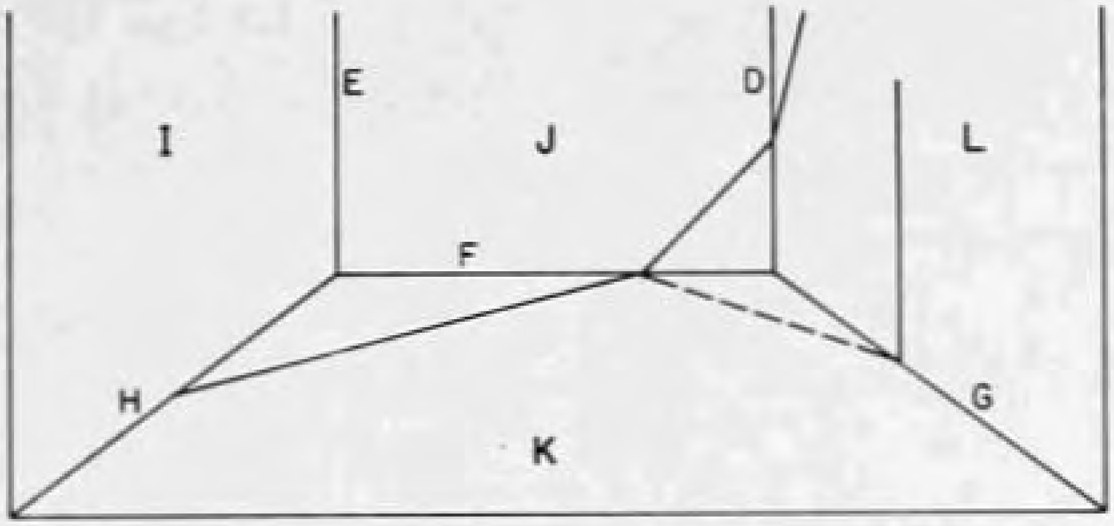


FIGURE 9. EFFECT OF A LABEL CHANGE.

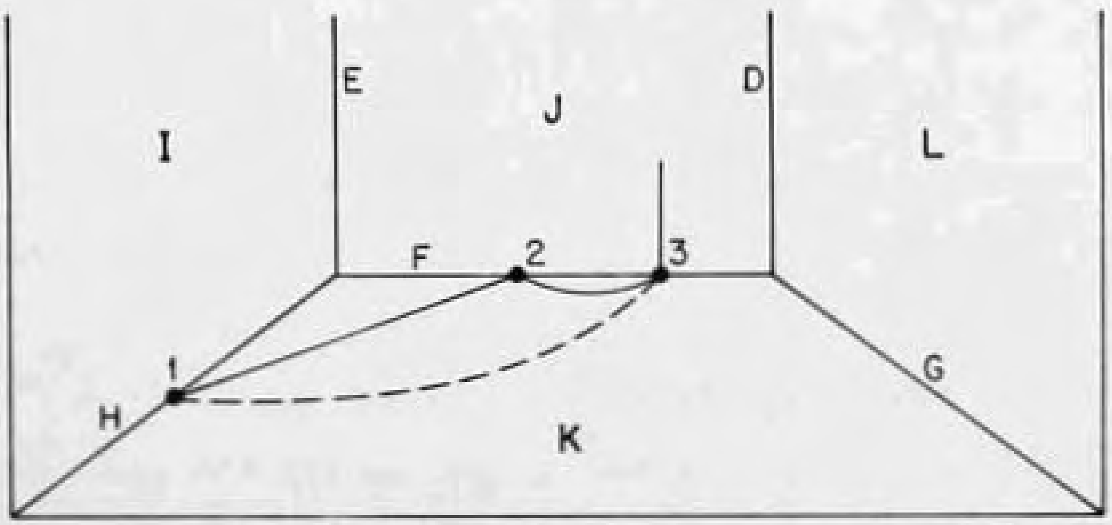


FIGURE 10. EFFECT OF A VARIATION IN DISTANCE ARRAY SEQUENCING.

w_{hhk} is the smaller, then the portion of the path in question utilizes nodes in K.

The computer solution of the algorithm requires a great deal of temporary tape storage to get from one step to the next. The distance arrays in certain instances may consume more storage area than that required for solving the entire network as a single network.

However, there are several reasons which make the algorithm useful and practical:

1. The distance arrays may be read individually into the same storage area through the use of equivalence statements.

2. The distance arrays need be calculated only once and then used in the calculation of all required tree tables.

3. Because the time required for the solution of the basic minimum path algorithm increases as a function of the number of nodes in the network, an actual time savings develops provided that the number of tree tables required is not too small.

The relationship between the time required to compute a tree table and the number of nodes is shown in Figure 11. If t is the time in seconds and N is the number of nodes in the network, the relationship is given by:

$$t = 0.55(N/100)^2$$

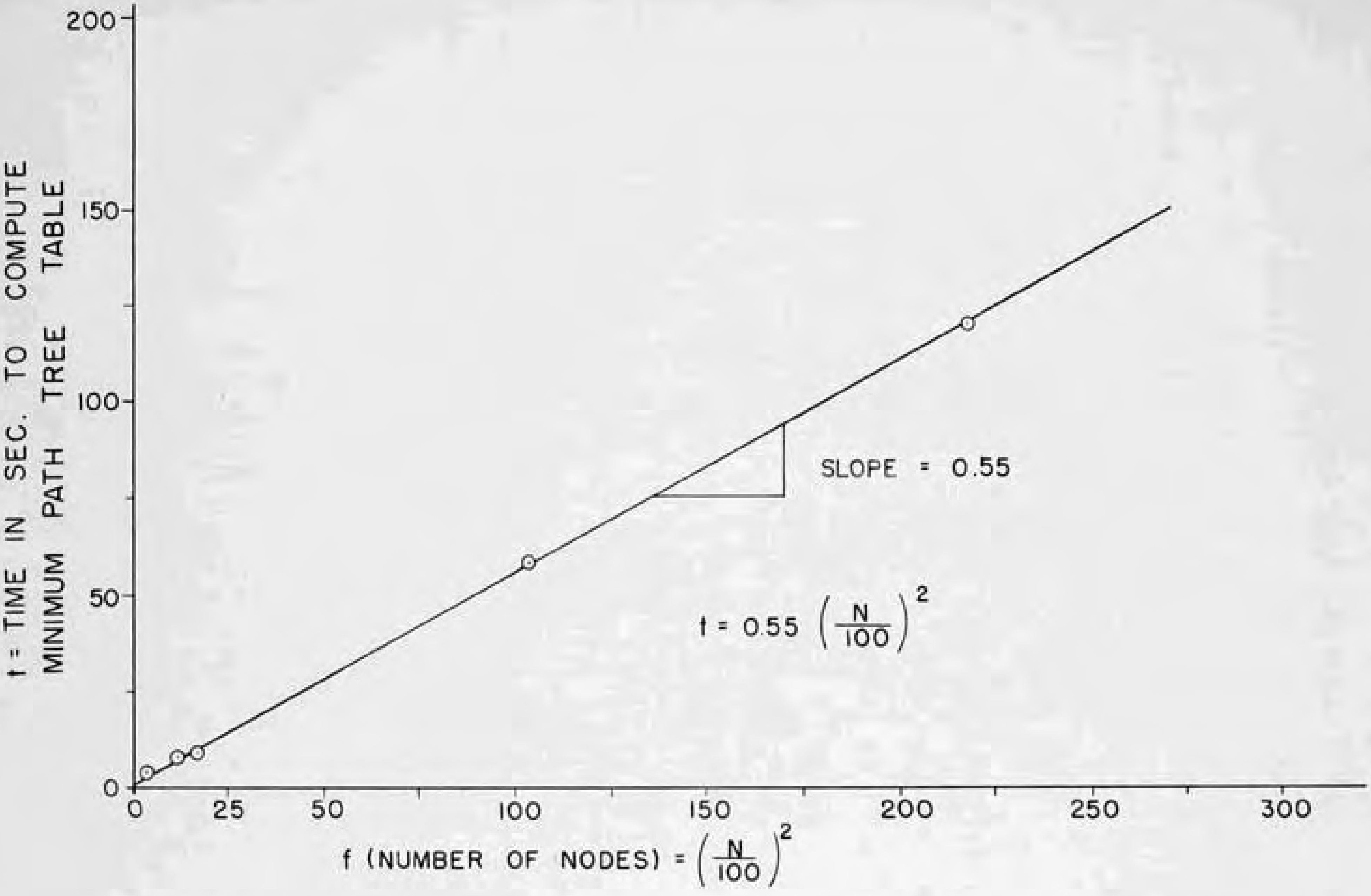


FIGURE 11. TIME - NODE RELATION FOR MINIMUM PATH SOLUTION

Based on this relationship, the time required to solve the entire highway network of 1837 nodes (for the Indiana highway problem, see Table 3) would be about 187 seconds. The completion of the tree table upon the incorporation of the centroid table would require some additional time so that an estimate for the complete tree table would be about 190 seconds.

The time required for the complete tree table using the decomposition algorithm was about 87 seconds for Indiana based centroids. This represented a time savings of approximately 103 seconds for each tree table.

A total of about 4410 seconds was required to generate the distance arrays necessary for solution with the decomposition algorithm. The number of tree tables that must be solved to break even with respect to time is 4410/103 or about 43. A total of 451 tree tables, one for each Indiana based centroid, were calculated in the analysis of travel desire factors.

DETERMINATION OF INTERCITY TRAVEL DESIRE FACTORS

Introduction

The procedure used in determining the Intercity Travel Desire Factors (ITDF) consisted first of finding the minimum path route between a pair of cities. The ITDF between the pair of cities was computed and assigned to each link making up the path provided that the link represented some portion of a highway within Indiana. As each city pair was investigated, a cumulative total of the ITDF's assigned to each link was maintained.

This analysis was performed in three phases with the cumulative total of ITDF link assignments kept separately for each phase. The phases were:

I. All city pairs formed when both cities were more than 100 miles from Indiana's border.

II. All city pairs formed with at least one city in Indiana.

III. All city pairs formed with at least one city within 100 miles of Indiana's border but neither within Indiana.

One of the major assumptions made in this analysis was that the entire 41,000 miles of the Interstate System was complete and open to traffic. The reason behind this assumption was that traffic patterns as they now exist will undergo some change upon completion of the Interstate system and a reclassified state highway system should reflect these anticipated changes. It was also thought that some insight might be gained to guide the selection of freeway standard highway sections to supplement the Interstate system.

Network Description

A total of five partitioned networks plus a sixth network (the Interstate system outside of the partitioned area) were coded such that the entire network consisted of 4582 nodes of which 2745 were centroids and 6345 links of which 3229 were centroid links.

The node and link sizes of the six networks are listed in Table 3. Each of the networks was coded in a slightly different manner as explained below.

Interstate Network

The first network coded was the Interstate network which was the only one required for Phase I. The assumption was made that all traffic between two cities where both were located more than 100 miles from Indiana's border, would utilize only Interstate routes in crossing Indiana.

A total of 301 nodes were designated at intersections and 450 individual links described. The link lengths were determined by use of a mechanical map measure and appropriate scale based on the state maps of the Rand McNally Road

Table 3. Size of Networks.

Area	Highway System		Cities	
	Links	Nodes	Links	Centroids
Interstate	450	301	1,639	1,639
Indiana	1,809	1,020	691	451
Michigan	186	108	178	125
Ohio	320	177	244	167
Kentucky	178	101	147	114
Illinois	259	163	330	249
Total	3,116	1,837	3,229	2,745

Atlas (48). The actual scaled distance was used as the link length for all Interstate links.

Each link required two description cards, one for the forward link and another for the back link. The cards were coded as shown below:

Node A	Node B	Link Length
Node B	Node A	Link Length

The numbering of the nodes extended consecutively from 1500 to 1800.

A total of 1639 cities, each with a population of 5000 or more, were coded as centroids. For convenience in performing the calculations of Phase I, the centroid links providing the connection of the centroid to the Interstate system were coded differently than the highway links.

The Interstate node most likely to serve as the entry point to the Interstate system was determined for each centroid. The distance from the centroid to the entry node was obtained as described above except that non-Interstate route miles were first multiplied by 1.33 prior to the addition of any Interstate route miles. The conversion factor of 1.33 was used to change miles to minutes assuming a speed of 45 MPH was maintained on non-Interstate routes and 60 MPH on Interstate routes. Thus, in effect, all distances used in all of the networks were a time measure in minutes based on a speed index of one mile per minute.

The description of each centroid link included three pieces of data: The most likely Interstate entry node, the link length, and the population of the centroid. All population data were obtained from the 1960 U. S. Census of Population (49).

Indiana Network

A total of 1020 highway nodes and 1809 links were needed to code the highway system of Indiana. The Interstate highways in Indiana were coded first using node numbers from 2001 to 2199. Link lengths were scaled directly from the 1966 Indiana State Highway Map as furnished by the Indiana State Highway Commission.

All U. S. numbered highways in Indiana were coded using node numbers 2201 to 2630. Link lengths were obtained from the Sufficiency Rating Report for Indiana State Highways (50). Prior to coding, the link lengths were converted to a time measure using the following speeds and conversion factors for the various highway typees:

4-lane rural	50 MPH	1.20
2-lane rural	45 MPH	1.33
4-lane urban	30 MPH	2.00
2-lane urban	15 MPH	4.00

The node locations coded up to this point are illustrated in Figure 12.

Next, all Indiana numbered highways were coded using node numbers 3001 to 3337. The link lengths were treated just as for U. S. numbered highways. Detailed illustrations of the complete Indiana highway network are shown in Figures

13 through 20. The link table is included in Appendix A, Table A1.

A total of 451 cities and towns in Indiana were coded as centroids using centroid numbers 656 to 1106. The breakdown of these cities by population was:

over 5000	70 cities
1000-5000	175 cities
100-1000	206 cities

Centroid links were coded similarly to the highway links with a forward link specifying the centroid number, the highway node number, and link length while the back link listed the highway node number, centroid number, and link length. A centroid located in juxtaposition with a node was coded only to that node with the link length taken as a function of population as follows:

over 5000	1.0 miles
1000-5000	0.5 miles
100-1000	0.2 miles

A centroid located along a link between two nodes was coded to both nodes such that the sum of the two centroid link lengths equaled the highway link length.

The populations of two cities within five miles of each other were summed and treated as a single city, the location of which was selected at some intermediate point.

The centroid table as used in this study is included in Appendix A, Table A2.

FIGURE 17. INDIANA HIGHWAY NETWORK - INTERSTATE AND U.S. NUMBERED ROUTES

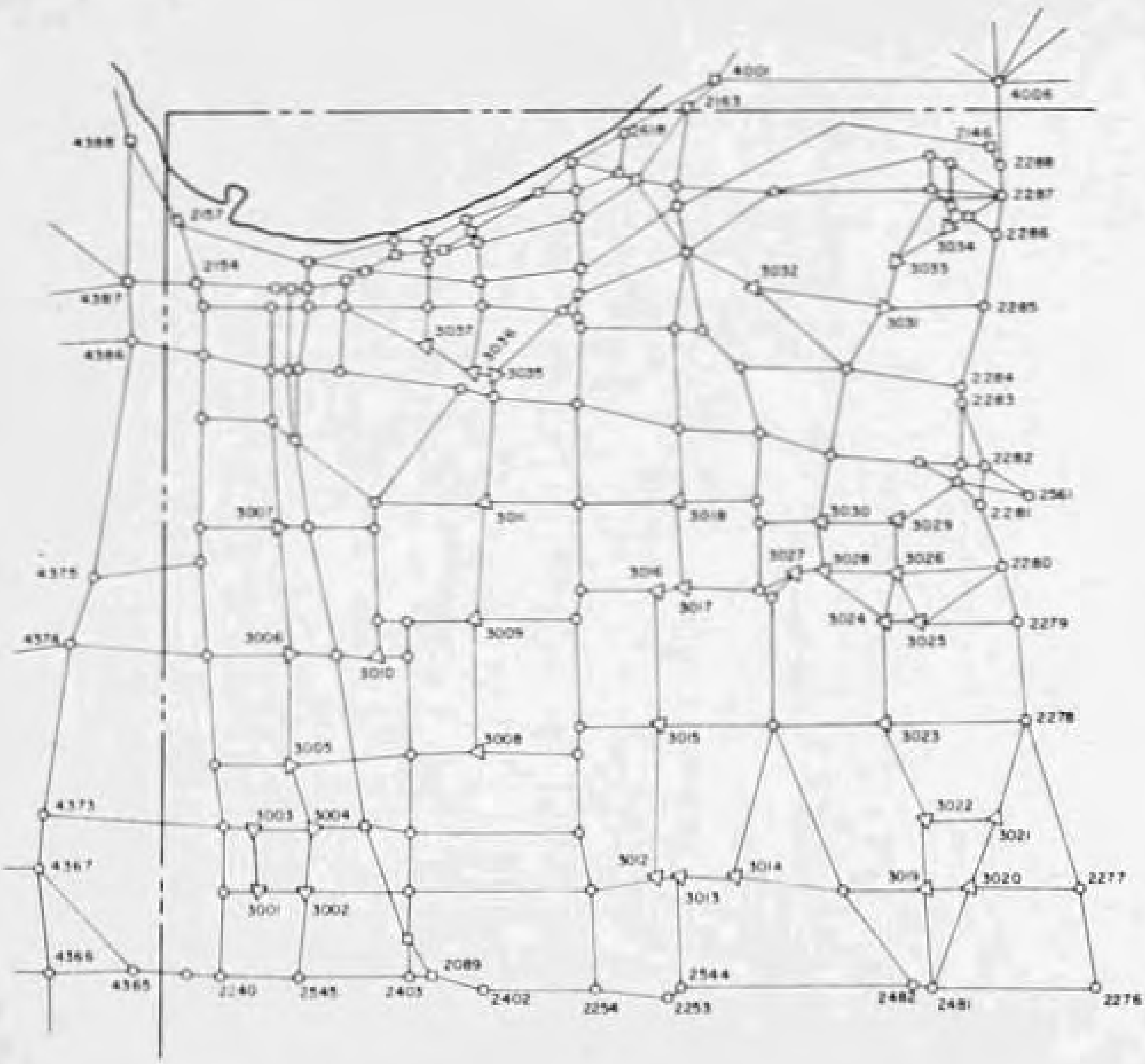


FIGURE 13. INDIANA HIGHWAY NETWORK - SECTION 901 - NORTHWEST CORNER

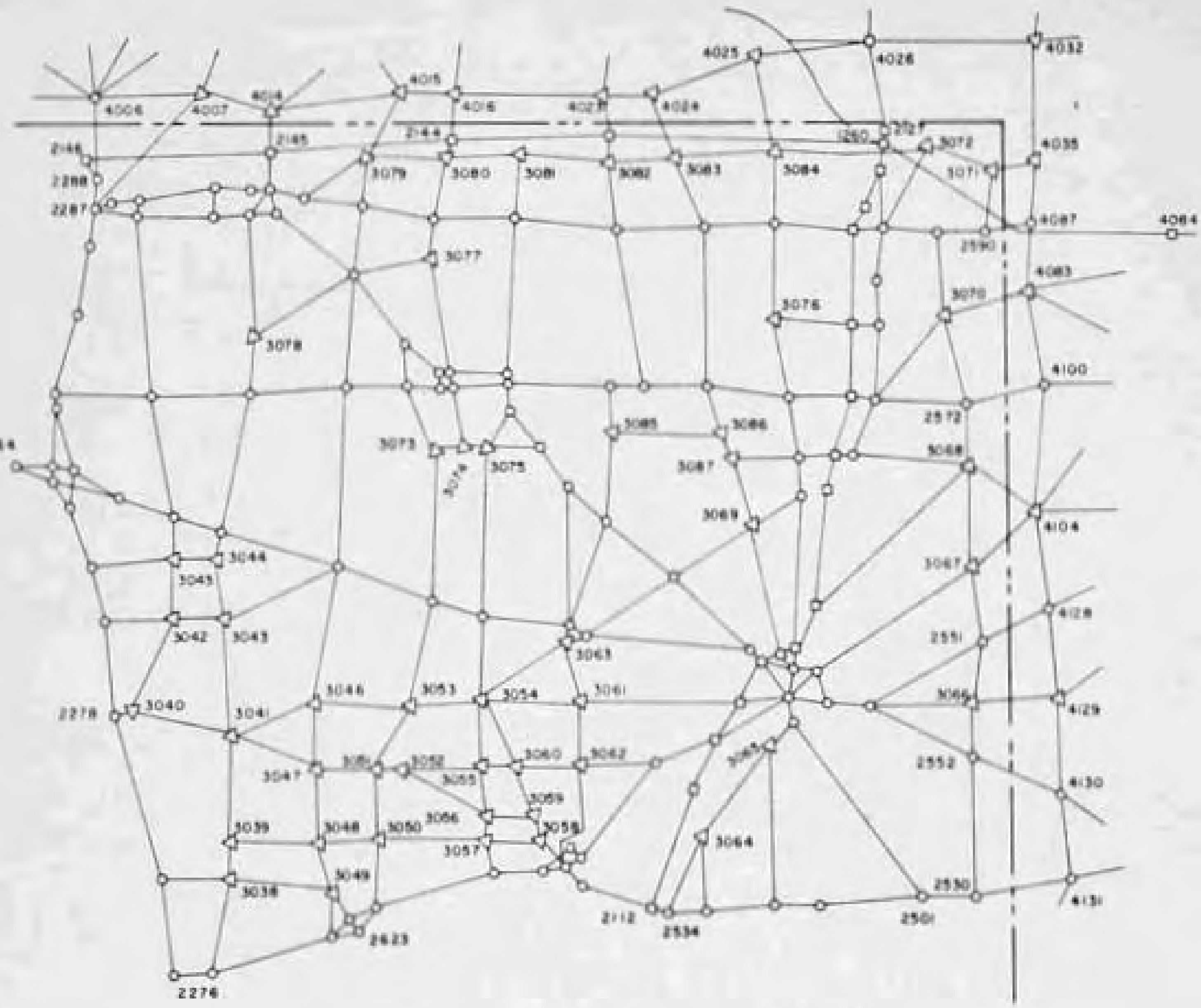


FIGURE 14. INDIANA HIGHWAY NETWORK - SECTION 902 - NORTHEAST CORNER

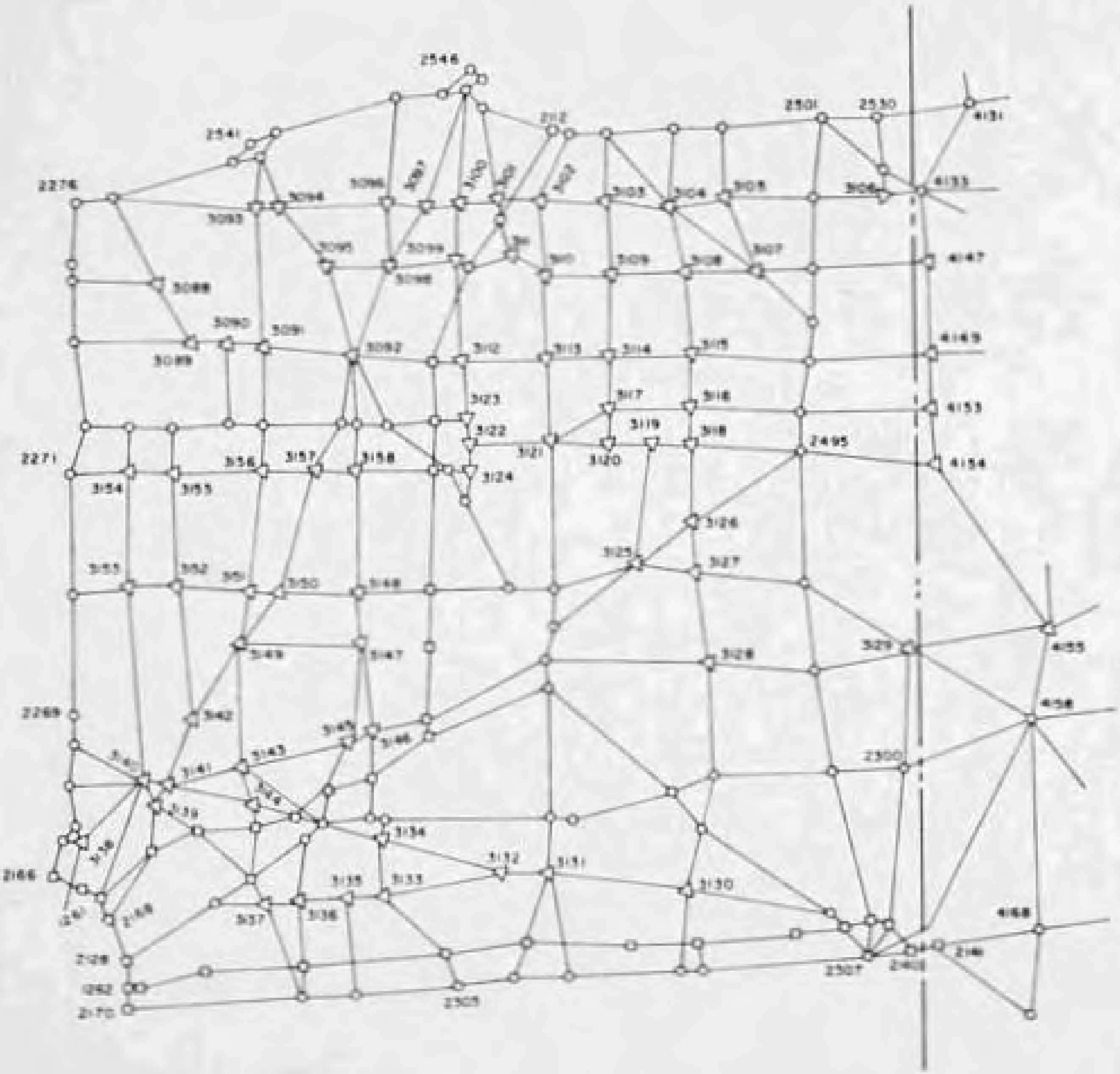


FIGURE 15. INDIANA HIGHWAY NETWORK — SECTION 903 — NORTHEAST CENTRAL

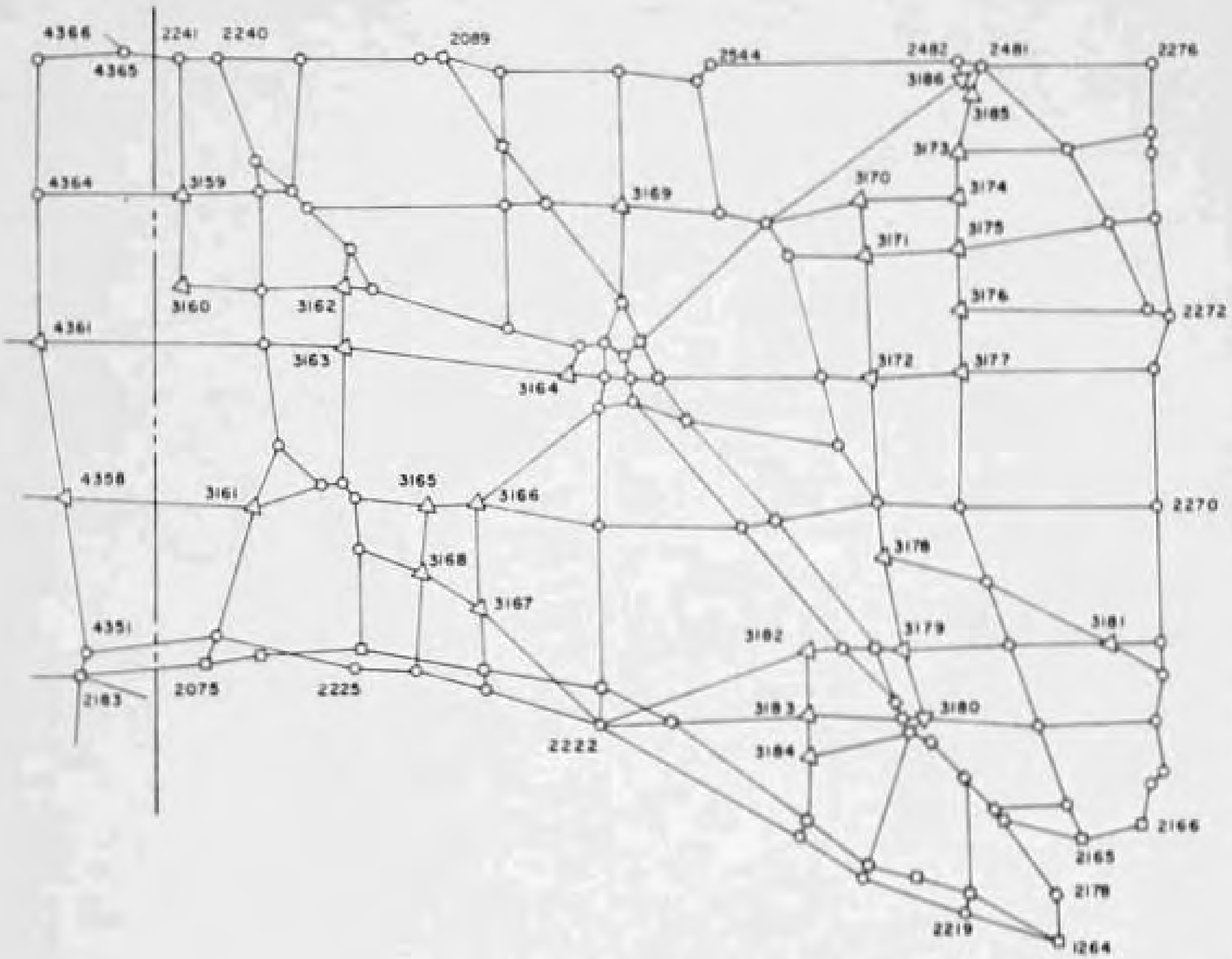


FIGURE 16. INDIANA HIGHWAY NETWORK – SECTION 904 – NORTHWEST CENTRAL

FIGURE 17. INDIANA HIGHWAY NETWORK – SECTION 905 – SOUTHEAST CORNER

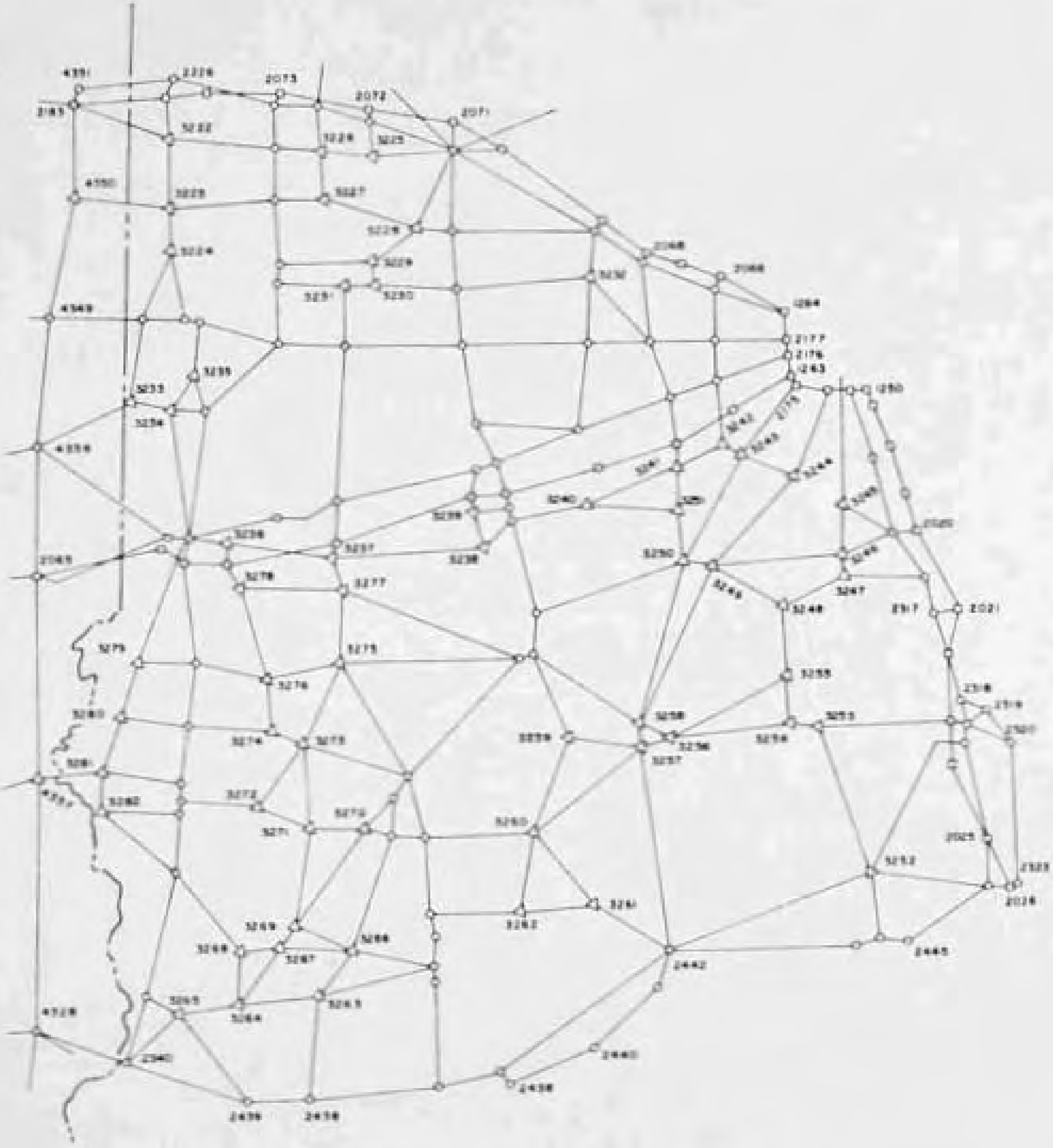


FIGURE 18. INDIANA HIGHWAY NETWORK – SECTION 906 – SOUTHWEST CENTRAL

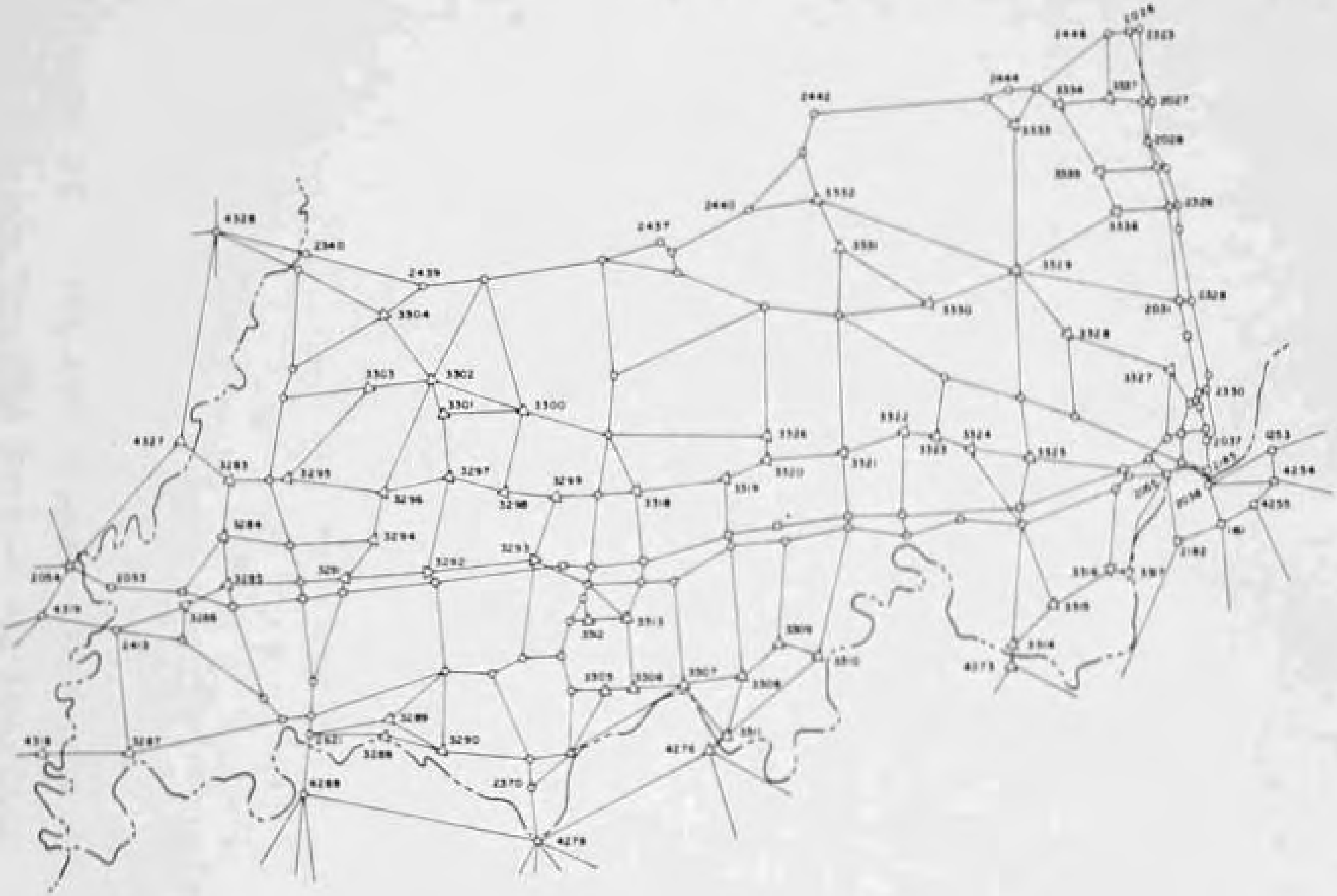


FIGURE 19. INDIANA HIGHWAY NETWORK – SECTION 907 – SOUTHWEST CORNER

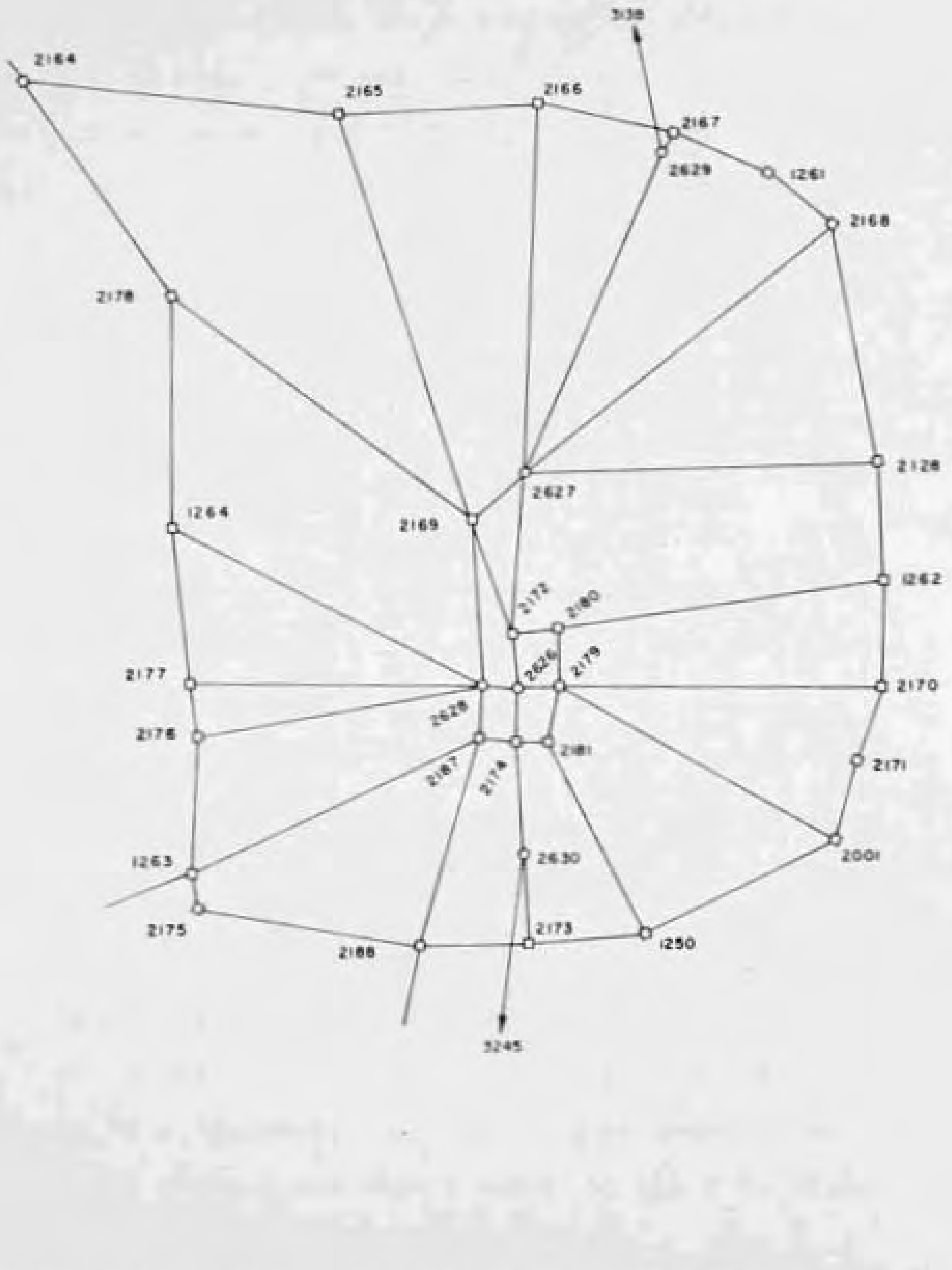


FIGURE 20. INDIANA HIGHWAY NETWORK – SECTION 908 – INDIANAPOLIS

Michigan Network

The Michigan, Ohio, Kentucky, and Illinois highway networks were each coded similarly. The networks extended a distance of 100 miles from Indiana's borders so that some portions of Tennessee, Missouri, and Wisconsin were also included.

All cities and towns of over 1000 population in this delimited area were coded as centroids. Several cities in Ohio and Illinois outside of the delimited area were included here because there was no most likely entry node available in the Interstate network.

The node and centroid number sequences as well as a population breakdown of the centroids are listed in Table 4 for each border state.

The highway and centroid link lengths were determined exactly as for the Indiana network except that distances were scaled from appropriate state highway maps.

Decomposed Network

The highway network used in this study was decomposed into five parts, which represented Indiana and portions of Michigan, Ohio, Kentucky, and Illinois as shown in Figure 21. A sixth network was that portion of the Interstate network not included in the other five parts.

Several assumptions and simplifications were made in the calculation of minimum paths using the decomposition algorithm.

Table 4. Node Numbers in Border States.

State	Node Numbers	Centroid		
		Numbers	Over 5,000	1,000-5,000
Michigan	4,001-4,092	1-125	39	86
Ohio	4,093-4,219	126-292	65	102
Kentucky	4,220-4,303	293-406	34	80
Illinois	4,304-4,409	407-655	98	151

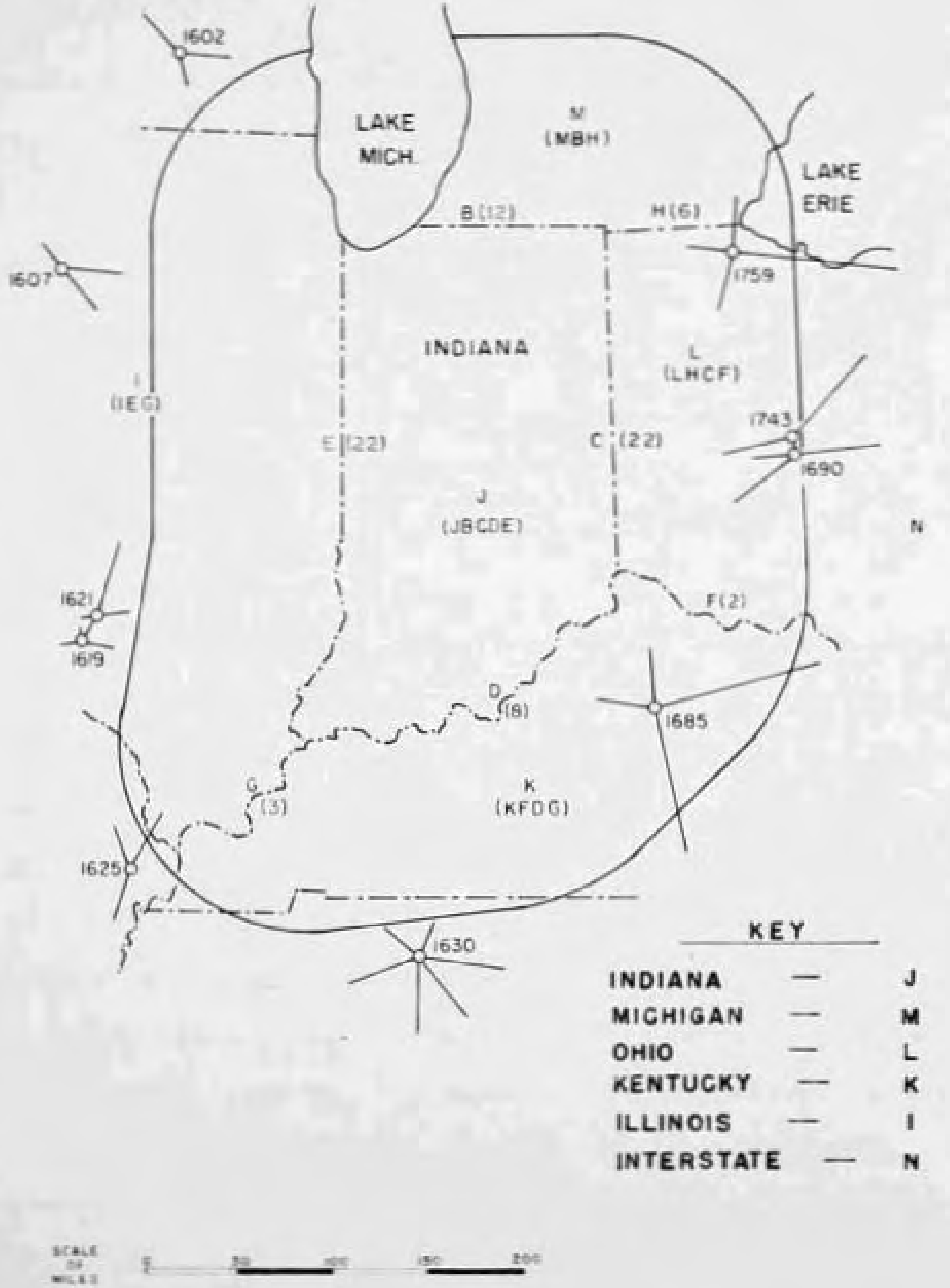


FIGURE 21. DELIMITED AREA OF THE PARTITIONED NETWORKS.

1. Travel between two cities within a state were assumed to utilize only highways within that state. This appears to be reasonable because the minimum path would probably not cross the state boundary unless the cities were close to the border, the border itself was not very straight, or a high type facility was available close to the border in the adjacent state. The borders as shown in Figure 21 are relatively straight, but the east-west Interstate highways closely paralleling the borders of Indiana at the north and south ends of the State may result in border crossings for travel between cities in both Michigan and Kentucky. These interactions were judged to be not significant, however.

2. The minimum paths from one centroid to all other centroids within the same state were not required for any state except Indiana. This greatly simplified the performance of the decomposition algorithm because it virtually eliminated step 4 (use of the link table to build minimum path trees to all other nodes from a source node) for all states but Indiana, requiring only the border node to centroid distance array to reach each border node. This assumption is justified for two reasons: first, travel factors for links in Indiana only were required, and secondly, such travel factors would not be affected if the first assumption is valid.

3. Travel between two cities, one of which was in Indiana, was assumed to cross Indiana's borders only once,

i.e., there would be no crisscrossing of a border. The same reasoning is applied here as for the first assumption.

These assumptions were not made primarily to reduce the magnitude of the computations but were made necessary due to physical limitations involving the computer. The principal limitation was the lack of sufficient tapes to maintain all the necessary intermediate data. Another concerned the conserving of time. At any rate, any errors introduced by these assumptions are considered negligible.

This judgment was reinforced by subsequent analysis. When the decomposition algorithm was applied to determine paths between cities in different border states, assumption 3 was not made because it was feasible to introduce the distance arrays required to check for the occurrence of crisscrossing. It occurred in only several instances and in every case was characterized by the fact that one of the cities was very close to the border and the crossings were made to utilize a section of Interstate highway.

Additional comments and discussion on the use of the decomposed network and algorithm will be made in the following sections on travel desire.

Travel Desire-Phase I

Phase I of the determination of Intercity Travel Desire Factors included all city pairs formed where both cities were located more than 100 miles from Indiana's border. The Interstate network consisting of 301 nodes and

450 links was used in this phase. All city pairs formed from a total of 1639 centroids were tested to determine if the minimum path between them utilized any Indiana Interstate routes. If so, the factor was calculated and assigned to those routes included in the minimum path.

A modified version of Small Trees, a computer program listed in Appendix B1, was used to determine all required minimum paths. A total of 10 Interstate system nodes and 23 links were included in Indiana. The first step was the formation of a distance array FINDR which included the minimum path distances from each of the 10 Interstate nodes within Indiana to each of the 301 nodes in the network.

The remainder of the procedure was confined to those Interstate nodes to which centroids were linked beginning with the lowest Interstate node number proceeding to the highest.

The tree table was first calculated for each node and the paths to it traced from all higher numbered nodes. If the path trace contained at least one of the 10 Interstate nodes located in Indiana, the path trace was printed. The route through Indiana was coded by a sequence of numbers from 1 to 23, each of which designated one of the 23 Interstate links in Indiana. Each individual route was assigned a code number from 1 to 29 which represented each of 29 different routes used in passing through Indiana.

Thus, for each different Indiana route employed in reaching the source node, a set of at least two data cards was generated. The first contained the source node number, the route number, and the total of higher numbered nodes which used the designated route to reach the source node. The second card (and others as required) listed the node numbers corresponding to the total given on the first card.

Each of the 29 routes was coded similarly. The first card listed the route number, the key node, and total links on the route while the second listed the link numbers. The key node was any one of the ten Interstate nodes within Indiana which was included in the route.

After each node had been used as a source node and all of the node-node interactions utilizing Indiana routes properly coded, the Intercity Travel Desire Factors were computed.

The distance d_{ij} was the sum of the four distances obtained from the input data. Two were the centroid to Interstate entry node distances obtained from the centroid table. The other two distances were the entry node to key node distances obtained from the FINDR array. The factor was computed and then assigned to each link on the route connecting the two centroids. A cumulative total of these factors was maintained for each link.

A total of 346,734 centroid interactions were computed for this phase of the analysis. The final total of Intercity Travel Desire Factors for each of the 192 Indiana highway links comprising the 29 Indiana Interstate routes are listed in Appendix A, Table A1 under the heading, Phase I.

Travel Desire-Phase II

Phase II of the determination of Intercity Travel Desire Factors included all city pairs formed with at least one city within Indiana. The area node and border node set code names used in the description of Phase II are shown in Figure 21. The number of nodes in each border set are in parentheses alongside the border set code name while the node sets used in generating the necessary minimum path trees are shown similarly within each area.

Figure 21 also shows 10 Interstate network nodes selected in such a way that the delimited area is bounded by them. Thus, the minimum path from any Interstate node outside the delimited area to any node within the delimited area must pass through at least one of these ten nodes, hereafter referred to as boundary nodes. All Interstate nodes within the boundary nodes are included in the appropriate area node sets of the partitioned networks.

The general procedure used to compute the Intercity Travel Desire Factors was as follows:

1. Select a source centroid in Indiana and using the JBCDE link table (listed in Appendix A, Table A1), calculate the minimum path tree table to all nodes and centroids within Indiana employing the computer program, Small Trees.

2. Use this tree table and the required distance arrays to generate an expanded minimum path tree table for all other centroids in the network employing the computer program, Expanded Trees.

3. With the expanded tree table and the centroid population arrays, compute the travel desire factor between a centroid and the source centroid, trace the minimum path node sequence, and assign the factor to each Indiana link on the path, employing the computer program, Trades.

4. Update the cumulative sum of travel desire factors calculated for previous source centroids by adding those calculated for the current source centroid.

Phase II was terminated when each Indiana centroid had been used as a source centroid.

Distance Arrays

The distance arrays required for use of the decomposition algorithm in Expanded Trees were generated first. These arrays as described below were generated by a modified version of Small Trees using the appropriate area link and centroid tables. Only the border nodes were used as source centroids in this step.

The required distance arrayss were:

DISTMC- The distances from all M (Michigan) centroids to the border nodes in sets B and H.

DISTLC- The distances from all L centroids to the border nodes in sets H, C, and F.

DISTKC- The distances from all K centroids to the border nodes in sets F, D, and G.

DISTIC- The distance from all I centroids to the border nodes in sets G and E.

DMBLLL- The distances from each node in H to all nodes in H, C, and F by way of nodes in L. The array name, DMBLLL, may be interpreted as follows: The distance (D) from all Michigan nodes bordering Ohio (MBL) to all nodes bordering Ohio (L) by way of nodes in Ohio (L). The companion array, DLBMMM, was generated but discarded because it was suspected and easily verified that all minimum paths from nodes in H to nodes in B were by way of nodes in areas L and J due to the presence of the Ohio and Indiana Turnpikes.

DKBLLL- The distances from each node in F to all nodes in F, C, and H by way of nodes in L.

DLBKKK- The distances from each node in F to all nodes in F, D, and G by way of nodes in K.

DIBKKK- The distances from each node in G to all nodes in G, D, and F by way of nodes in K.

DKBIII- the distance from each node in G to all nodes in G and E by way of nodes in I.

DISTMN- The distances from each Interstate node (N) included in the Michigan area node set, MBH, including boundary nodes, if any, to the border nodes in B and H.

DISTLN, DISTKN, DISTIN- Each of these is interpreted similarly to DISTMN but for each of the other three border states.

NNATND, NACEND, DISTNC- This is a link table generated by using each of the boundary nodes as a source centroid with the Interstate network. NNATND is one of the boundary nodes. NACEND is a centroid linked, Interstate node connected to a boundary node at a distance, DISTNC. Note that this is not a distance array in the same sense as those described above.

Small Trees

Small Trees is a computer program listed in Appendix B1. It was used to solve the basic minimum path algorithm with the Indiana network link table for a source centroid within Indiana. The details concerning the basic minimum path algorithm were given in a previous chapter.

The mechanics of Small Trees are outlined briefly in Appendix B1.

Expanded Trees

Expanded Trees is a computer program listed in Appendix B2. It was used to extend the tree table calculated by Small Trees to include the minimum path distances to all other centroids in the network. The details concerning the decomposition algorithm for large networks were given in the previous chapter.

The mechanics of Expanded Trees are outlined briefly in Appendix B2.

Trades

Trades is a computer program listed in Appendix B3. It was used to calculate the Intercity Travel Desire Factors between the source centroid and all other centroids and assign the factors to each link on the routes connecting each centroid pair.

Trades as originally programmed exceeded available storage by about 3000 locations. The Interstate centroid array required 4917 locations for the three data elements of each of 1639 centroids. Because many centroids utilized the same Interstate entry node, it was reasoned that the sum of centroid populations and an average distance to the Interstate entry node could be substituted for the group of centroids, thus reducing the storage requirements. This procedure was subject only to the provision that any error introduced was negligible.

The form of the travel desire factor used in this study was the product of the square roots of populations of two centroids divided by the square of the distance between them:

$$ITDF_{ij} = (P_i \ P_j)^{1/2}/d_{ij}^{\ 2}$$

The desired simplification would be of the form:

$$\sum_j ITDF_{ij} = (P_i \sum_j P_j)^{1/2}/(d_{in} + \bar{d})^2$$

where n is the Interstate entry node and i, the source centroid. It was found that the accuracy of the simplification depended on three things:

1. The average distance must be based on the square roots of population rather than on population,

2. The less variable the d_{nj} distances were, the more accurate the simplification, and

3. The larger the value of the constant distance d_{in}; the more accurate the simplification.

Therefore, the following procedure was used in providing the simplification. The average distance was computed as:

$$\bar{d} = \frac{d_{n1} \sqrt{P_{n1}} + d_{n2} \sqrt{P_{n2}} + \ldots}{\sum_j \sqrt{P_{nj}}}$$

and the travel desire as

$$\sum_j ITDF_{ij} = (P_i)^{1/2} \left[\sum_j (P_{nj})^{1/2} / (d_{in} + \bar{d})^2 \right]$$

In order to reduce the effects of the variability in the d_{nj}, $\bar{d}$ was calculated for each of five distance ranges for each Interstate entry node. The ranges were 0 to 100 miles, 100 to 300 miles, 300 to 600 miles, 600 to 1000 miles, and over 1000 miles.

Because there were only 86 Interstate entry nodes and only a few with distances in all five ranges, a total of 181 Interstate centroid cards requiring 543 storage locations were needed.

This procedure was verified with the actual data used in the study and the error introduced was insignificiant.

The mechanics of Trades are outlined briefly in Appendix B3.

Update Trades

Because of time limitations imposed on the length of jobs run on the computer, the three programs -- Small Trees, Expanded Trees, and Trades -- could be run in succession for only about 35 to 40 source centroids at a time. Therefore, after each run it was required that the output of Trades be added to that of all previous Trades and the result stored on another tape.

A total of 209,393 centroid interactions were computed for this phase of the analysis. The final totals of Intercity Travel Desire Factors for each of the 2510 Indiana centroid and highway links are listed in Appendix A, Tables A1 and A2 under the heading, Phase II.

<u>Travel Desire-Phase III</u>

Phase III of the determination of Intercity Travel Desire Factors included all city pairs formed with at least one city within 100 miles of Indiana's borders but neither within Indiana. The centroids used in this portion of the analysis were restricted to those with a population of 5000 or more. The area node and border node set code names used in the description of Phase III are shown in Figure 21.

The general procedure used to compute the Intercity Travel Desire Factors was as follows:

1. Select a source centroid from one of the border states and, using the required distance arrays, calculate the minimum path tree table to all nodes and centroids employing the computer program, Border Trees.

2. Determine the portion of the path consisting of Indiana highway links and the centroid pairs connected by each different path.

3. With the data of step 2 and the centroid population arrays, compute the travel desire factor between a centroid and the source centroid and assign the factor to each Indiana highway link on the path employing the computer program Tradet.

Phase III was terminated when each border state centroid had been used as a source centroid.

Distance Arrays

The distance arrays required for use of the decomposition algorithm in Border Trees were generated first. These arrays as decribed below were generated by a modified version of Small Trees using the appropriate area link and centroid tables. Only border nodes were used as source centroids in the step and only those centroids with a population of over 5000 were considered.

Several distance arrays required for Border Trees were also required for Expanded Trees. These were defined in the previous section, Travel Desire-Phase II and are simply listed here: DISTMC, DISTLC, DISTKC, DISTIC, DMBLLL, DKBLLL, DLBKKK, DIBKKK, DKBIII, DISTMN, DISTLN, DISTKN, DISTIN, and the link table providing connections from the boundary nodes to centroid linked, Interstate nodes, NNATND, NACEND, and DISTNC.

Other distance arrays required were:

DISTML- The distance from each node in B to all nodes in C by way of nodes in J, i.e., the distance from the Michigan-Indiana border nodes to the Ohio-Indiana border nodes as calculated using the JBCDE link table.

DISTMK- The distance from each node in B to all nodes in D by way of nodes in J.

DISTMI- The distance from each node in B to all nodes in E by way of nodes in J.

DISTLK- The distance from each node in C to all nodes in D by way of nodes in J.

DISTLI- The distance from each node in C to all nodes in E by way of nodes in J.

DISTKI- The distance from all nodes in D to each node in E by way of nodes in J.

DMBJMJ- The distance from each node in B to all nodes in B by way of nodes in either M or J, i.e., the distance from each Michigan-Indiana border node to all other Michigan-Indiana border nodes where the entry in the distance array was the minimum of two possible paths, the first entirely in Michigan and the second entirely in Indiana. In effect, two distance arrays were combined into one by this procedure.

DLBJLJ- The distance from each node in C to all nodes in C by way of nodes in either L or J.

DKBJKJ- The distance from each node in D to all nodes in D by way of nodes in either K or J.

DIBJIJ- The distance from each node in E to all nodes in E by way of nodes in either I or J.

Border Trees

Border Trees is a computer program listed in Appendix B4. It was used to solve the decomposition algorithm for determining minimum paths in large networks.

The mechanics of Border Trees are outlined briefly in Appendix B4.

Tradet

Tradet is a modified version of Trades, a computer program listed in Appendix B3. It was used to calculate the Intercity Travel Desire Factors between each centroid pair and assign the factors to each link on the Indiana portion of the routes connecting them.

The output of Border Trees was coded in a manner similar to that used for Travel Desire-Phase I. For each source centroid, the distance array to all other centroids was card punched. The Indiana portion of each route connecting a centroid to the source centroid was assigned a route number and all centroids utilizing that route were so coded.

A total of 87 different routes utilizing Indiana highways were needed to account for all centroid interactions where the source centroid was located in Michigan. For source centroids in Ohio, Kentucky, and Illinois, the number of different routes was 91, 58, and 46 respectively.

The mechanics of Tradet and Trades are similar but with several exceptions. The path tracer and the centroid pairs utilizing each path trace (route) were read in for Tradet but had to be determined from the tree table in Trades. It was possible to compute all the travel desire factors in one computer run with Tradet but ten were required to complete Trades.

A total of 33,814 centroid interactions were computed for this phase of the analysis. The final totals of Intercity Travel Desire Factors for each Indiana link involved are listed in Appendix A, Table A1 under the heading, Phase III.

Summary

The methodology employed in computing the Intercity Travel Desire Factors representative of Indiana highways has been presented in this chapter. The travel desire factors are listed in Appendix A opposite the link each represents.

In Phases I and III of this analysis, the centroid pairs and the route connecting each pair were coded and card punched. This was done with the intention that other forms of a travel desire factor besides that used could be tried. However, this was not feasible in Phase II because virtually every centroid pair was connected by a different route. An analysis of other forms of a travel desire factor could have been performed if sufficient tapes were available to store the expanded tree table for each Indiana source centroid.

The number of centroid interactions computed in Phases II and III as reported above are in error because of the grouping of Interstate centroids made necessary to reduce computer storage requirements as described in the subsection, Trades. If this is corrected, an estimate of the number of centroid interactions computed in this analysis is:

Phase I	346,734
Phase II	311,453
Phase III	130,000

for a total of approximately 790,000 interactions.

ANALYSIS OF INTERCITY TRAVEL DESIRE FACTORS

Introduction

The purpose of this chapter is to demonstrate the adequacy of the assumed ITDF model to synthesize travel. Current and past traffic volume data could not be used directly as the system analyzed was the current Indiana State Highway System with the Interstate System complete. The ITDF model used in this study was the product of the square roots of the populations of a city pair divided by the square of the minimum path distance between the cities.

The number resulting from this calculation for a city pair was then assigned to each link making up the minimum path sequence. A cumulative total was kept for each link so that, after all city pairs had been considered, each link was represented by an Intercity Travel Desire Factor, hereafter called the factor.

Because the factors were computed in three Phases, some links had more than one factor associated with them. In Phase I, the assumption was made that all centroid interactions would be assigned to Interstate routes only; hence, only these had a non-zero Phase I factor. This assumption was not made in Phase III but, nevertheless, the greater proportion of the Phase III factors were for Interstate routes. This development indicated that the assumption of only Interstate route assignments in Phase I appeared reasonable. Furthermore, more than three-fourths of the Indiana state highway links had only factors resulting from Phase II.

Because of the way in which the network was coded, each Indiana centroid had a Phase II factor associated with it which represented the magnitude of its interaction with all other centroids, i.e., when the centroid served as an origin or destination for interaction with other centroids. This meant that the factors associated with the links coming into a centroid could be separated into what may be termed a centroid attraction factor and a thru factor.

All of the factors are listed in the Link Table and Centroid Table of Appendix A.

The analysis of the factors was performed in two parts, a centroid and a link analysis.

Centroid Analysis

It has previously been stated that the completion of the Interstate highway system and its subsequent utilization by traffic will result in changes in the traffic patterns now existing on the state highway system. Because of the fact that the Interstate system was assumed to be completed in the performance of this study, the factors should reflect travel patterns not as they currently exist but as they would exist if the Interstate system were complete or as they will exist in approximately 1972 (the scheduled completion date of the Interstate system) provided that growth is more or less uniform. For this reason, it was decided that the establishment of a relationship between link volumes, as they currently exist, and link factors would not provide an adequate means of demonstrating the adequacy of the ITDF model to synthesize travel although a link analysis to establish such a relationship was necessary if the factors were to serve their function as a highway classification tool.

However, it was reasoned that even though the traffic patterns would be changed, the relative magnitude of traffic attracted by individual centroids would not be affected by assuming a completed Interstate system. This implies that the traffic attracted to a centroid should be essentially the same but that it may enter the centroid on different links. Also, it must be recognized that the amount of traffic which currently passes thru a city might be significantly altered if the Interstate system were complete.

The impact of this latter effect on the total traffic entering or leaving a city decreases as city size increases as shown in Table 5 from Matson, Smith, and Hurd (53). Table 5 gives the per cent of traffic entering a city which may be bypassed (traffic not desiring to stop in the city) around the city as a function of city size. The percentage of bypassable traffic for cities from 10,000 to 300,000 population is relatively uniform appearing to average about 20 per cent. Because of the high proportion of traffic

Table 5. Proportion of Approaching External Traffic which May Be Bypassed Around A City.

Cities by Population Size	Per Cent Bypassable Traffic
Less than 2,500	50.7
2,500 - 10,000	43.3
10,000 - 25,000	21.9
25,000 - 50,000	21.0
50,000 - 100,000	16.2
100,000 - 300,000	18.2
300,000 - 500,000	7.2
500,000 - 1,000,000	4.2

having a terminus in these cities, it appeared reasonable to expect that a significant relationship should exist between the sum of the computed factors and the sum of the traffic volumes for the links entering these cities even if significant changes in thru traffic would occur with a completed Interstate system, provided that the ITDF model was adequate. In other words, a high percentage of the variability of traffic volume should be explained by a regression of the sum of the traffic volumes for the links serving the centroid on the Phase II centroid attraction factor.

In order to test this reasoning, several regression analyses were performed utilizing the Stepwise Regression program, BMD-2R, as developed by the Health Sciences Computing Facility at UCLA (43).

The dependent variable Y was taken as the sum of the Annual Average Daily Traffic (AADT) estimates on all highways entering a city as measured just beyond the city limits. This data was collected from the 1962 Traffic Map as furnished by the Indiana State Highway Commission (55). The independent variables were various measures of the computed factors associated with the links entering each centroid.

Data for a total of 390 Indiana centroids were coded for use in this analysis. These data sets were divided into three centroid population groups. The first group consisted of 69 centroids, each with a population of over 5000, the second of 167 centroids, each with a population between 1000 and 5000, and the third of 154 centroids, each with a population between 100 and 1000. A regression analysis was performed on each of these three data sets as well as on the total of 390 data sets.

The division of data sets by population was performed to test the reasoning that the adequacy of the ITDF model would decrease as population decreased as measured by the per cent of variability of the dependent variable explained by the independent variables. The per cent of variability explained is commonly referred to as the coefficient of determination or the square of the correlation coefficient (R^2) in regression analysis.

It was also expected that an increase in R^2 would occur when the thru factors associated with the links serving a centroid were included in the analysis. However, it was also recognized that a serious problem concerning the effects of local traffic existed for the smaller cities in addition to the thru traffic effects. The situation as it generally exists for small cities is that traffic volumes on roads entering the city are correspondingly small. A good deal of this traffic may be bound for the city but be local in character. The amount of local traffic is a function of the population density in the surrounding area and the degree of agricultural and other economic development. These factors have wide variation throughout the State so that a similar variation should be expected in the amount of local traffic as well.

Each of these effects serve to force a decrease in R^2 as city size decreases because the amount of thru and local traffic assumes a much greater significance with respect to the total traffic entering the city than does the intercity traffic attracted by the city. This would be expected to occur even if the ITDF model perfectly explained intercity travel desire.

The results of the regression analyses performed on the centroid data are given in Table 6. The values of R^2 are shown to decrease from 0.829 to 0.218 to 0.116 for large, medium, and small city sizes respectively when the centroid attraction factor is the only independent variable. However, the values of R^2 are increased to 0.879, 0.479, and 0.419 respectively when the thru factor measures of Phases I, II, and III also serve as independent variables. These results are in agreement with the discussion given above.

The values of R^2 for the data taken as a whole range from 0.816 when the centroid attraction factor is the only independent variable to 0.872 when the three thru factor measures are also included.

Based on these results, it appears reasonable to conclude that the assumed ITDF model is an adequate measure of intercity travel desire.

A perplexing aspect of the models developed in this analysis, however, is the negative sign of some of the coefficients for the Phase I and Phase III thru factors, i.e., X_3 and X_4. (See Table 6) The implication is that traffic

Table 6. Regression Models Developed in the Centroid Analysis.

Dependent Variable	Parameter	Independent Variables X_1	X_2	X_3	X_4	R^2
$Y_{(>5000)}$	Coeff.	70.62	---	---	---	0.829
	Std. Err.	3.92	---	---	---	
	Coeff.	55.72	2.63	---	---	0.873
	Std. Err.	4.63	0.56	---	---	
	Coeff.	55.56	4.16	-1.61	-2.24	0.879
	Std. Err.	4.61	0.98	2.18	1.69	
$Y_{(1000-5000)}$	Coeff.	42.66	---	---	---	0.218
	Std. Err.	6.28	---	---	---	
	Coeff.	21.55	28.75	---	---	0.428
	Std. Err.	6.04	0.37	---	---	
	Coeff.	21.17	4.64	4.54	-7.36	0.479
	Std. Err.	5.82	0.65	1.76	1.87	
$Y_{(<1000)}$	Coeff.	61.48	---	---	---	0.116
	Std. Err.	13.74	---	---	---	
	Coeff.	34.09	2.27	---	---	0.291
	Std. Err.	13.15	0.37	---	---	
	Coeff.	20.23	6.63	1.00	-6.75	0.419
	Std. Err.	12.23	0.85	1.48	1.24	
$Y_{(ALL)}$	Coeff.	58.67	---	---	---	0.816
	Std. Err.	1.42	---	---	---	
	Coeff.	47.85	2.77	---	---	0.866
	Std. Err.	1.51	0.23	---	---	
	Coeff.	47.34	4.37	-0.36	-2.98	0.872
	Std. Err.	1.48	0.43	0.95	0.80	

Y = Sum of AADT's on links entering a centroid.
X_1 = Sum of Phase II centroid attraction factors.
X_2 = Sum of Phase II thru factors.
X_3 = Sum of Phase I thru factors.
X_4 = Sum of Phase III thru factors.

decreases as the thru factors associated with a centroid increases. This makes no sense at all.

An explanation for this occurrence is an extension of the thru traffic effect as described previously. Thru traffic makes up a relatively small proportion of the external traffic entering a city and it may be assumed that the type of thru traffic supposedly measured by the Phase I and Phase III factors constitutes a small proportion of the thru traffic. Thus, other traffic variations such as in local traffic probably overwhelm any variability in traffic volume that may be explained by the Phase I and Phase III factors. This was borne out by examination of the standard errors which revealed that many of the coefficients of X_3 and X_4 are not significantly different from zero.

The high value of some of the Phase I and Phase III factors leads to the conclusion that they are overestimated relative to Phase II factors. In other words, the ITDF model yields too high an intercity travel desire for the very long interactions characteristic of Phase I and Phase III. Many of these long trips are either not made at all or are made by another mode such as plane or train. Thus, for long distance trips of say 300 to 400 miles or more, the exponent of distance in the ITDF model should be some value greater than two.

Link Analysis

A link analysis was performed to develop a relationship between link volumes and link factors. A regression analysis of the minimum AADT associated with a link on the Phase II link factor was performed to develop this relationship.

The minimum AADT on a link (the lowest AADT of a section of the link) was used as the dependent variable because the minimum value would more closely reflect intercity travel as shown in Figure 22. In this idealized relationship, it can be seen that local traffic increases as a centroid or route intersection is approached but intercity traffic remains constant. Thus, the minimum traffic volume more closely represents what the ITDF model measures.

Only the Phase II link factor was used in the link analysis for two reasons; namely over three-fourths of the links had zero values for Phase I and Phase III factors and the results of the centroid analysis showed that the numerical values of the factors from the three phases were not additive. The establishment of a relationship between the three factors is a research topic in itself.

The link data used in this analysis were selected to meet one of two criteria: the link was located in an area remote from Interstate highway rights-of-way or the link was located near portions of the Interstate system completed prior to 1962. These criteria were imposed in an attempt to

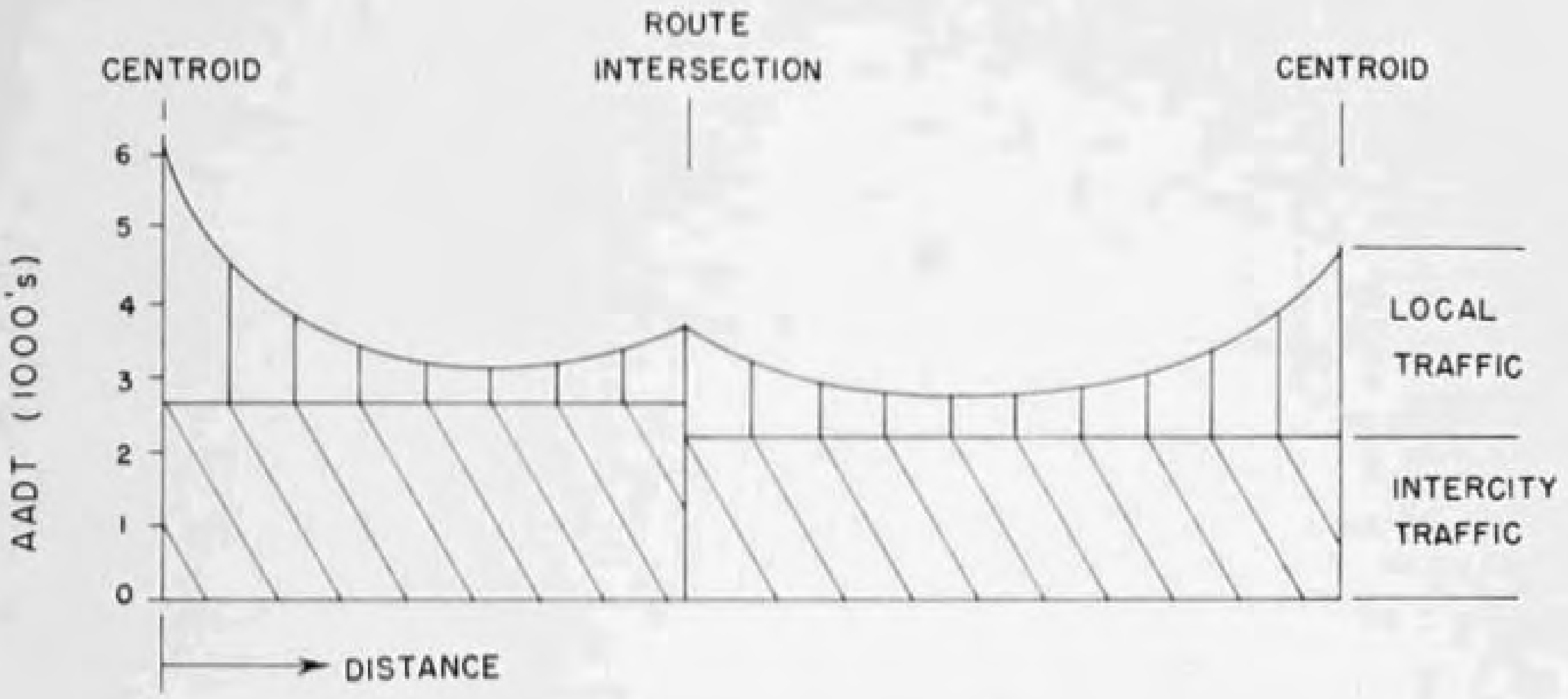


FIGURE 22. IDEALIZED RELATIONSHIP OF INTERCITY AND LOCAL TRAFFIC WITH DISTANCE

insure that travel patterns in the areas of the selected links would not be significantly affected by completion of the entire Interstate System.

After the link data had been collected and plotted on a scatter diagram, it was decided to eliminate those data sets having a Phase II link factor of less than 50 and to try a functional relationship of the form:

$$Y = a + b \text{ Log}(X)$$

where Y is the minimum link AADT and X is the Phase II link factor.

A total of 126 data sets were used in this analysis. The regression model developed was:

$$Y = -8977 + 5523 \text{ Log}_{10}(X)$$

which had an R^2 of 0.919. A plot of this equation is shown in Figure 23.

The variance of the estimate, $s_{\hat{Y}}^2$, of a predicted Y for a given X is estimated by:

$$s_{\hat{Y}}^2 = s_E^2 \quad [1 + \frac{1}{n} + \frac{(X - \bar{X})^2}{\Sigma(X - \bar{X})^2}]$$

For X equal to the mean, the variance of the estimate is given by:

$$s_{\hat{Y}}^2 = 551{,}412 \; [1 + \frac{1}{126} + \frac{(2.377 - 2.377)^2}{25.43}]$$

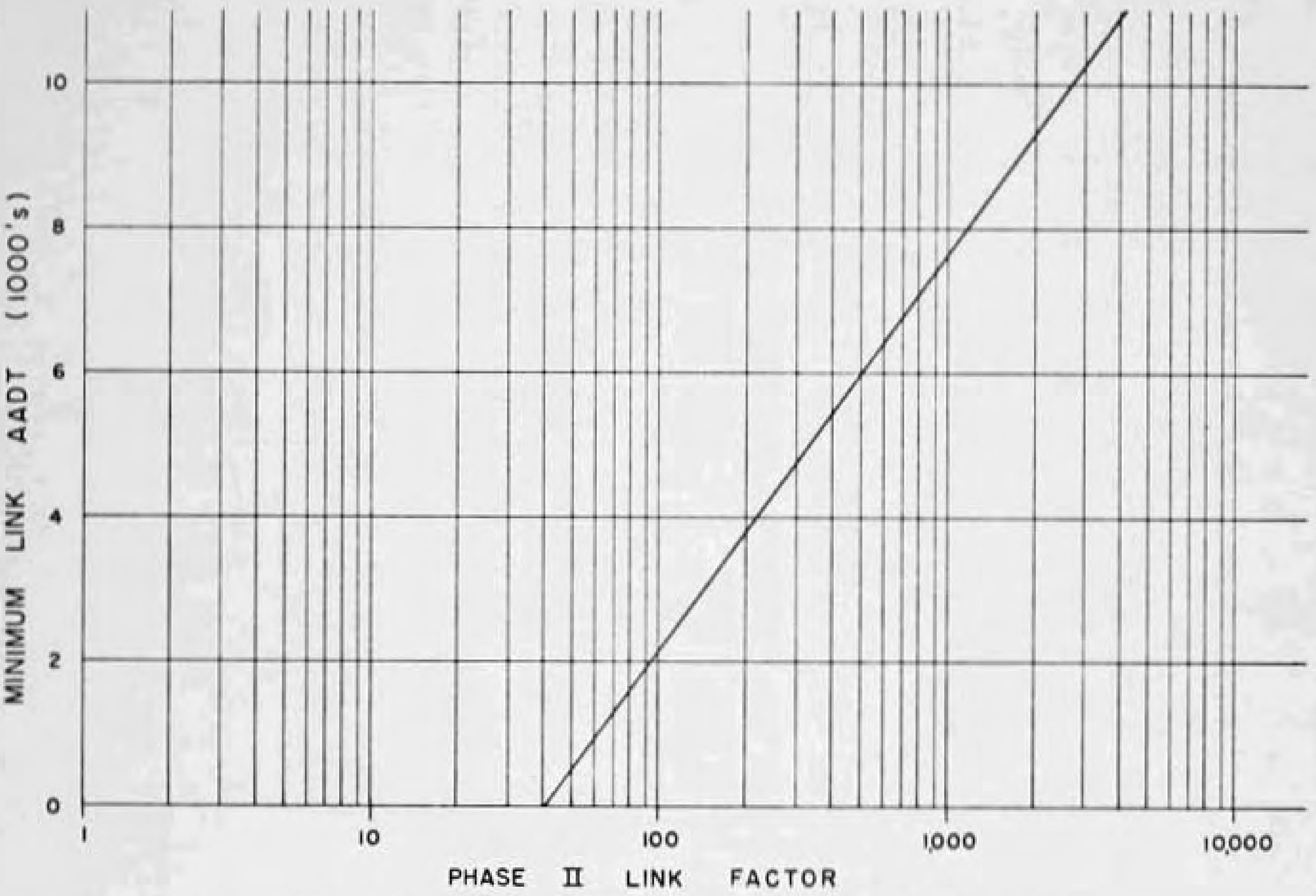


FIGURE 23. LINK VOLUME AS A FUNCTION OF LINK FACTOR

and the standard error of the estimate, $s_{\hat{Y}}$, equals 745.5.

The standard error of the slope was 147.3 so that the 95 per cent confidence interval extended from 5,234 to 5,812.

Based on this analysis, it was decided that the regression model is an adequate means of predicting the traffic volume associated with the Phase II link factor. Furthermore, these results reinforce the conclusion that the ITDF model used is adequate for the synthesis of travel demand.

CONCLUSIONS AND APPLICATION OF RESULTS

Conclusions

Conclusions which were reached during the course of this research included the following:

1. The tree type decomposition algorithm is a practical method for computing minimum path trees for large networks and can result in a substantial reduction in computer time if the number of tree tables required is not too small.

2. The Intercity Travel Desire Model used in this research is an adequate method of synthesizing travel demand.

3. The Phase I and Phase III portions of the determination of intercity travel desire reflected thru traffic demand but not in a manner which permitted summation with each other or with the factors of Phase II. Furthermore, these Phases need not be determined in any future study as the factors found from Phase II were adequate for classification purposes.

4. For cities outside of the delimited study area, only those with a population of more than 10,000 or 20,000 should be considered in calculating the travel desire factors. Factors for the smaller cities are virtually negligible because of the long distances involved.

5. The relationship:

$$Y = -8997 + 5523 \text{ Log}_{10}(X)$$

where Y is the AADT and X is the Phase II link factor, was found to be an acceptable highway classification tool for Phase II link factors of 65 or greater. The limiting value of 65 represents a traffic volume of about 1,000 vehicles per day.

Some representative volumes and the factors found to be associated with them are:

Volume	Factor
1,000	65
2,000	97
3,000	148
4,000	225
6,000	522
10,000	2,700

Application of Results

It is proposed that the State Highway System of Indiana be subclassified into four designated systems. These four subsystems are:

1. Principal State Highway System. This system should be composed of the presently designated Interstate highway system and those highways which, on the basis of their Phase II Intercity Travel Desire Factor and other planning criteria should be reconstructed to freeway standards by 1982.

The design year was selected as 1982 because the AADT-link factor relationship was based on 1962 volume data thus providing a 20 year planning interval.

2. Primary State Highway System. This system should be composed of the additional highways required to provide for the interconnection with the Principal State Highway System of all Indiana cities over 5000 population and should also include those roads having a Phase II link factor of at least 125.

3. Secondary State Highway System. This system should be composed of the additional highways required to provide for the interconnection with the previously designated subsystems of all still unconnected county seats and should also include those highways having a Phase II link factor of at least 50.

4. Collector State Highway System. This system should include the remainder of the present State Highway System of Indiana not already in a previously designated subsystem.

The proposed Principal State Highway System for 1972 and 1982 is shown in Figure 24. The routes proposed as supplementary to the Interstate system are shown in two groups. The first consists of freeways deemed necessary by 1972 and the second, freeways deemed necessary by 1982.

In general, when the AADT of a two-lane, two-way highway lies somewhere about 7,000 to 8,000 vehicles per day, serious consideration should be given to making it a

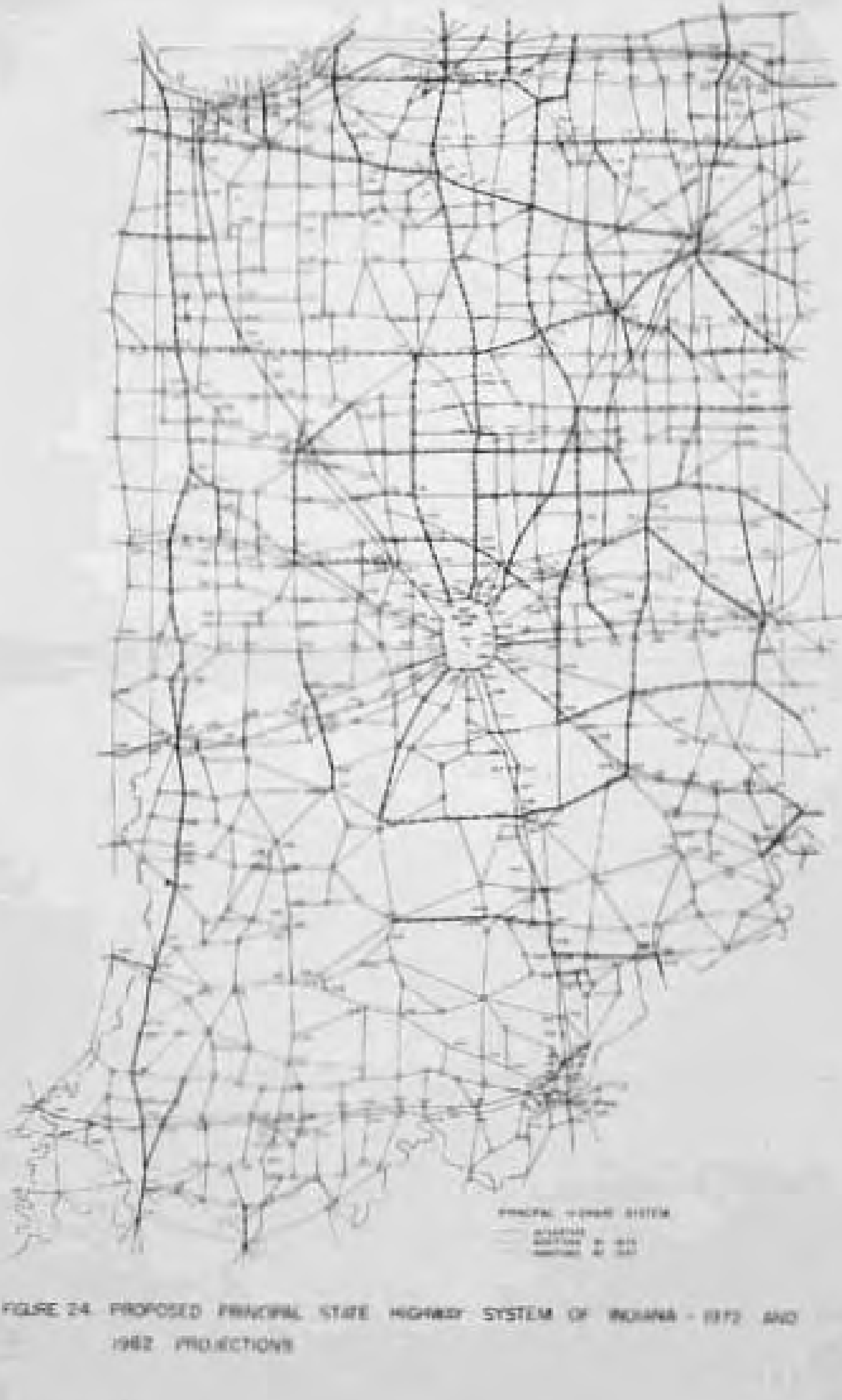


FIGURE 24 PROPOSED PRINCIPAL STATE HIGHWAY SYSTEM OF INDIANA - 1972 AND 1982 PROJECTIONS

multilane facility with the degree of access control determined by individual study. If the design hour volume (DHV) is taken at about 15 per cent of the AADT, its magnitude is 1,050 to 1,200 vehicles per hour for AADT's of 7,000 to 8,000 respectively.

According to the "Highway Capacity Manual" (56), the service volume for level of service C approaches 1400 passenger cars per hour under ideal conditions while the service volume for level of service B approaches 900 passenger cars per hour under ideal conditions. Level of service B is associated with the design of rural highways while level of service C merely implies satisfactory operating conditions.

The service volume at level of service C on a two-lane highway with adequate lane and shoulder width, no passing sight distance or alinement restrictions, and only 10 per cent trucks is about 1,200 vehicles per hour. Thus, demand volumes of about 1,100 to 1,200 vehicles per hour virtually dictate multilane design even if ideal conditions can be designed into a two-lane highway and if a desirable level of service is to be attained.

The selection of the Phase II link factor limits used to select this subsystem of highways was based on a projected volume of 7500 vehicles per day assuming an annual average growth rate of four per cent. Highways in Indiana which will be carrying this volume of traffic by 1972 are those which had a link factor of 350 or more as calculated in this study. Those which had a link factor of 180 to 350 will require multilane design between 1972 and 1982.

The four subsystems of the State Highway System of Indiana as suggested by this research for 1972 are shown in Figure 25.

The Primary State Highway System includes those highways with link factors between 125 and 350. The lower value is representative of a 1962 traffic volume of about 2,600 vehicles per day so that, with a four per cent annual growth rate, the 1972 volume would be about 4,000 vehicles per day.

This projected volume of 4,000 was used because it represents the point at which high standards for two-lane rural highway design are often recommended by state highway departments. This proposed system for 1972 also includes those highways with link factors between 180 and 350 which are suggested for transfer to the Principal System between 1972 and 1982.

The Primary System was also selected to ensure the interconnectivity of cities over 5,000 with the Principal System. Similar nearby cities in adjacent states as well as the major routes of adjacent states were also considered.

The Secondary State Highway System was selected to provide for the interconnection of all county seats and also to provide a general coverage of all areas of Indiana. A minimum link factor of 50 was used because its use appeared

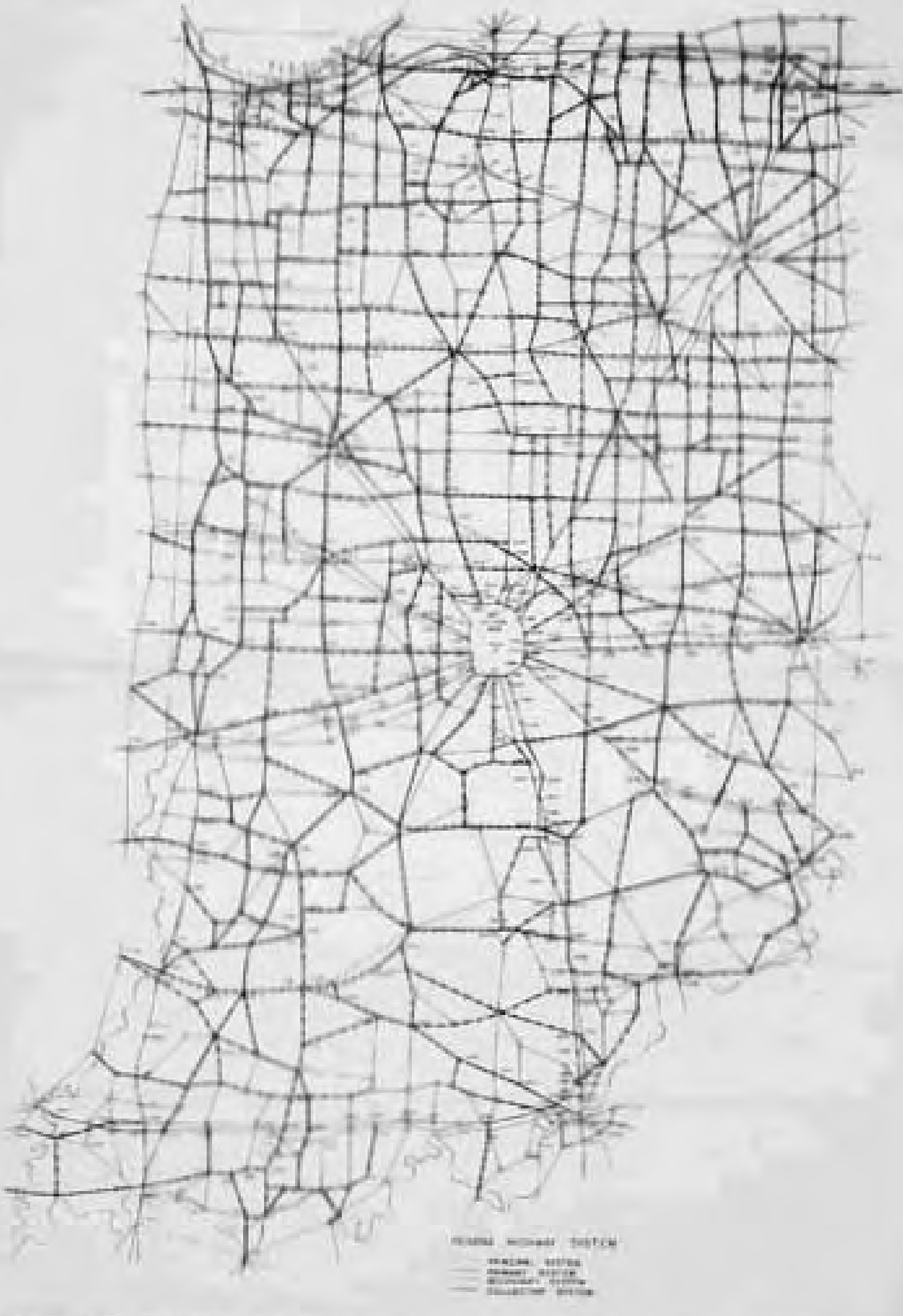


FIGURE 25. PROPOSED SUBCLASSIFICATION OF THE STATE HIGHWAY SYSTEM OF INDIANA - 1972 PROJECTIONS

to provide good overall service to most areas of the State and included most highways with a 1972 volume of approximately 1,000 vehicles per day or more. Most of the small Indiana cities would be served by this system.

With regard to the selection of each of the four subsystems, it is important to note that the factor limits of each subsystem were not strictly adhered to in all cases. Each subsystem was selected so that it was integrated with previously designated subsystems and so that there were no isolated sections unconnected to either an equal or higher system.

Thus, some flexibility in selecting the subsystems was necessary to achieve an integrated, interconnected highway system serving all areas of the State.

The remaining highways in the current State highway system, after selection of the three subsystems discussed above, includes some highway sections which should be considered for deletion from the State highway system. Their low, in some cases zero, link factor indicates that the service they provide is local in character and that the counties, rather than the State, should be responsible for them. All the remaining highways, however, are shown in Figure 25 as belonging in the Collector System.

RECOMMENDATIONS FOR FURTHER RESEARCH

Based on the preceding analyses and conclusions, the following further research is recommended:

1. The optimum number of partitionings of large networks and the influence of the relative size of each partitioning should be determined for use of the tree type decomposition algorithm with regard to both the accessibility of the required data and the savings of computer time.

2. The relative efficiency of both computer storage and time requirements should be determined for the tree type decomposition algorithm with respect to matrix type decomposition algorithms and also with respect to the basic minimum path algorithm when programmed for high storage capacity computers.

3. The results of this study should be updated and the synthesis procedures refined by means of a comprehensive traffic survey covering the entire State of Indiana or at least a portion of it. This traffic survey should be conducted in 1970 when data on population will be gathered by the U. S. Bureau of Census. The traffic survey should include sample data on volumes, out-of-state vehicles, truck traffic, roadside origin-destination surveys along rural roadways and at cordon lines around cities, and other desired information.

These data will then enable conduct of the following needed research on intercity traffic desire models:

a. Determination of the effect of distance between cities on intercity traffic volumes.

b. Determination of the best intercity traffic desire model for estimation of intercity traffic volumes.

4. Land use or other type models designed to explain the amount of locally generated traffic entering urban areas and that which exists on rural highways should be developed. These models should then be combined with an intercity travel desire model to give a more comprehensive picture of the relative importance of highways.

5. The link factors developed in the Phase II portion of this study should be combined with the Sufficiency Ratings of the various highway sections to calculate the priority of highway sections for improvement or reconstruction to adequate standards or for the preparation of plans for construction of new facilities to replace existing highways.

6. An economic model should be devised to properly allocate available funds to the four State highway system subclasses proposed in this study.

7. A study is recommended to determine the necessary additions to the proposed Primary and Secondary State Highway Subsystems in Indiana to accommodate such special purposes as service to airports, institutions, recreational areas, and military installations.

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APPENDIX A

HIGHWAY LINK AND CENTROID LINK DESCRIPTIONS

APPENDIX A

HIGHWAY LINK AND CENTROID LINK DESCRIPTIONS

Table A1. Highway Link Table.

NODE A	NODE B	DIST-ANCE	PHASE I	PHASE II	PHASE III	NODE A	NODE B	DIST-ANCE	PHASE I	PHASE II	PHASE III
	INT	44									
2053	2054	5.0	223.1	652.3	547.9	2042	2043	8.0	223.1	878.7	528.5
2052	2053	8.0	223.1	652.3	547.9	2041	2042	5.8	223.1	982.2	528.5
2051	2052	5.8	223.1	669.1	547.9	2040	2041	12.9	223.1	973.6	580.5
2050	2051	7.5	223.1	690.4	547.9	2039	2040	12.4	223.1	1015.0	528.5
2049	2050	4.2	223.1	644.9	502.0	2039	2193	3.0	223.1	1114.0	528.5
2048	2049	10.0	223.1	881.4	535.4	2036	2193	3.1	517.0	1044.3	460.1
2047	2048	14.1	223.1	817.6	460.9	2035	2036	1.3	517.0	1044.3	512.1
2046	2047	2.8	223.1	817.6	460.9	2035	2192	2.8	517.0	478.8	651.0
2045	2046	5.8	223.1	749.4	460.9	2055	2193	2.5	293.9	404.2	97.4
2044	2045	9.6	223.1	901.2	528.5	2055	2182	7.0	293.9	404.1	97.4
2043	2044	5.6	223.1	878.7	528.5						
	INT	65									
2038	2185	2.0	645.8	3361.9	1272.6	2076	2199	3.0	613.7	3277.1	1989.4
2037	2186	3.8	645.8	2605.8	1272.6	2076	2077	3.7	613.7	3202.7	1988.7
2037	2193	1.0	645.8	2605.8	1072.3	2077	2078	1.8	613.7	3202.7	1988.7
2034	2192	2.6	716.6	2027.0	821.0	2078	2079	1.3	613.7	2980.6	1988.7
2033	2034	1.2	716.6	2018.9	821.0	2079	2080	1.3	613.7	2750.8	1970.4
2032	2033	6.3	716.6	2275.7	881.4	2080	2081	4.5	613.7	2635.0	1970.4
2031	2032	4.0	716.6	2275.7	881.4	2081	2082	11.9	613.7	2437.7	1970.4
2030	2031	10.1	716.6	2296.4	881.4	2082	2083	10.6	613.7	2613.1	1970.4
2029	2030	4.5	716.6	2409.4	881.4	2083	2084	3.6	613.7	2623.1	1970.6
2028	2029	3.2	716.6	2531.0	881.4	2084	2085	3.0	613.7	2644.0	1973.1
2027	2028	6.5	716.6	2474.1	881.4	2085	2086	3.1	613.7	2451.4	1973.0
2026	2027	8.4	716.6	2430.8	881.4	2086	2087	9.2	613.7	2408.4	1973.0
2025	2026	5.7	716.6	2272.8	881.4	2087	2088	5.6	613.7	2649.6	1973.0
2024	2025	8.3	716.6	2129.8	881.4	2088	2089	8.1	613.7	2636.9	1973.0
2023	2024	4.2	716.6	2129.8	881.4	2089	2090	2.6	613.7	2640.3	1955.0
2022	2023	7.2	716.6	2364.0	881.4	2090	2091	9.7	613.7	2575.6	1954.4
2021	2022	6.7	716.6	2230.6	881.4	2091	2092	16.3	613.7	2745.7	1954.4
2020	2021	9.2	716.6	2385.9	881.4	2092	2093	10.4	613.7	2414.1	1931.7
2019	2020	4.3	716.6	2715.4	881.2	2093	2094	7.2	613.7	2635.1	1931.7
2018	2019	4.9	716.6	2848.5	881.4	2094	2095	5.5	613.7	2857.3	1930.0

TABLE A1 (CONTINUED)

2017	2018	5.0	716.6	3202.7	881.4	2095	2096	5.5	613.7	3005.3	1896.6
2017	2191	1.6	716.6	3364.7	881.4	2096	2190	1.1	613.7	3005.3	1894.3
2164	2190	1.0	654.8	3242.9	1987.6	2156	2190	1.8	1822.3	1338.9	1271.4
		INT 69									
2097	2105	5.0	31.8	3003.8	242.4	2113	2114	4.6	31.8	1776.0	255.0
2097	2098	4.3	31.8	2222.8	242.4	2114	2115	4.1	31.8	1756.2	243.0
2098	2099	4.8	31.8	2370.6	242.4	2115	2116	4.1	31.8	2050.1	278.2
2099	2100	3.7	31.8	2304.5	242.4	2116	2117	1.6	31.8	1973.9	273.3
2100	2101	3.7	31.8	2245.0	242.4	2117	2118	1.4	31.8	1700.3	243.0
2101	2102	3.6	31.8	2385.4	284.9	2118	2119	4.2	31.8	2061.9	243.0
2102	2103	7.0	31.8	2386.4	284.5	2119	2120	9.5	31.8	2038.9	243.0
2103	2104	.9	31.8	2677.9	296.0	2120	2121	3.0	31.8	2038.9	243.0
2104	2105	6.0	31.8	2337.9	296.0	2121	2122	5.2	31.8	2236.6	243.0
2105	2106	6.8	31.8	2387.0	296.0	2122	2123	5.8	31.8	2260.7	225.1
2106	2107	10.0	31.8	2602.8	296.7	2123	2124	7.0	31.8	2187.6	225.1
2107	2108	4.4	31.8	2260.3	300.3	2124	2125	2.3	31.8	2033.2	225.1
2108	2109	6.8	31.8	2518.6	300.3	2125	2126	3.7	31.8	2033.2	225.1
2109	2110	8.6	31.8	2607.1	276.1	2126	2104	2.3	31.8	2166.1	223.7
2110	2111	4.8	31.8	2212.6	276.1	2127	2194	1.0	140.0	1436.8	752.2
2111	2112	9.6	31.8	1800.3	275.6	2127	4076	13.0	140.0	1434.8	750.6
2112	2113	10.5	31.8	1776.0	253.5						
		INT 70									
2140	2141	7.0	1637.5	3606.3	1790.0	2129	2106	.9	1637.5	2332.5	1855.0
2139	2140	3.0	1637.5	3110.3	1790.0	2056	2107	7.0	1462.6	2360.8	1074.4
2138	2139	1.4	1637.5	3219.6	1838.4	2056	2057	6.7	1462.6	2360.8	1075.1
2137	2138	2.7	1637.5	3130.6	1838.4	2057	2058	8.4	1462.6	2440.3	1075.1
2136	2137	4.2	1637.5	2588.2	1852.5	2058	2059	9.9	1462.6	2440.3	1075.1
2135	2136	9.2	1637.5	2588.2	1852.5	2059	2060	3.4	1462.6	1973.0	1075.1
2134	2135	6.3	1637.5	2659.0	1852.5	2060	2061	15.2	1462.6	1973.0	1075.1
2133	2134	9.7	1637.5	2659.0	1852.5	2061	2062	11.4	1462.6	1982.2	1075.1
2132	2133	6.8	1637.5	2870.0	1852.5	2062	2063	4.4	1462.6	1982.2	1075.1
2131	2132	11.9	1637.5	2606.1	1852.5	2063	2064	3.0	1462.6	1657.9	1074.1
2130	2131	8.0	1637.5	2332.5	1852.5	2064	2065	12.0	1462.6	1657.9	1074.1
2129	2130	5.6	1637.5	2332.5	1852.5	2141	4168	8.0	0.0	3095.1	1697.6
		INT 74									
1749	2016	4.0	14.0	2090.2	1304.7	2002	2003	3.5	14.0	1877.4	1262.5
2015	2016	7.0	14.0	1848.8	1304.7	2001	2002	2.1	14.0	1951.5	1262.5
2014	2015	5.0	14.0	1616.5	1304.7	2066	2108	7.4	301.1	1002.6	927.1
2013	2014	8.3	14.0	1902.1	1304.7	2066	2067	4.3	301.1	1030.8	952.8
2012	2013	6.4	14.0	1989.1	1304.7	2067	2068	3.7	301.1	1040.7	961.0
2011	2012	7.3	14.0	2012.5	1304.7	2068	2069	5.6	301.1	1011.8	961.0
2010	2011	7.8	14.0	2012.5	1304.7	2069	2070	12.5	301.1	879.0	961.0
2009	2010	2.0	14.0	1702.9	1304.7	2070	2071	5.9	301.1	1143.1	979.3
2008	2009	9.1	14.0	1702.9	1304.7	2071	2072	8.8	301.1	1322.1	945.4
2007	2008	4.2	14.0	1749.1	1304.7	2072	2073	9.1	301.1	1459.2	945.4
2006	2007	3.1	18.0	1794.9	1304.7	2073	2074	8.0	301.1	1359.8	922.3
2005	2006	2.6	14.0	1811.2	1304.7	2074	2075	4.3	301.1	1342.2	918.7
2004	2005	4.5	14.0	1795.7	1262.5	2075	2183	11.0	301.1	1363.1	946.6
2003	2004	9.8	14.0	1794.9	1262.5						

TABLE A1 (CONTINUED)

INT 80											
2194	4086	26.0	2496.7	1590.5	3199.6	2147	2148	10.0	2367.4	1247.8	2645.5
2143	2194	23.0	2367.4	1418.4	2722.7	2148	2149	8.0	2367.4	1288.5	2645.5
2143	2144	13.0	2367.4	1558.9	2704.6	2149	2150	10.0	2367.4	1556.0	2678.8
2144	2145	16.0	2367.4	1475.9	2697.5	2150	2156	5.0	0.0	1547.4	2533.8
2145	2146	15.0	2367.4	1568.9	2522.0	2156	2157	12.0	1822.3	1924.4	3805.1
2146	2147	28.0	2367.4	1515.2	2645.5	2157	4388	13.0	1822.3	1924.6	3805.1
INT 96											
2154	4387	6.0	1340.6	4159.2	2973.3	2158	2159	3.7	239.4	1435.5	2574.0
2153	2154	6.2	1340.6	1083.3	2973.3	2159	2160	3.0	239.4	1457.4	2574.0
2152	2153	1.1	1340.6	1083.3	2973.3	2160	2161	8.4	239.4	1001.1	2574.0
2152	2100	1.2	1340.6	1083.3	2973.3	2161	2162	5.0	239.4	1106.8	2573.4
2151	2100	3.3	2586.8	1857.5	2710.0	2162	2163	7.3	239.4	820.6	2574.0
2150	2151	1.6	2586.8	1857.5	2710.0	2163	4001	2.0	239.4	1114.7	2574.0
2150	2158	2.9	239.4	1845.9	2574.0						
INT 275											
1749	2186	10.0	0.0	1019.7	702.9	2186	4222	13.0	0.0	907.5	702.9
INT 665											
2173	2191	2.3	2284.1	1541.1	581.8	2128	2196	2.7	84.0	3014.9	247.4
2173	2188	2.1	2284.1	1547.6	581.8	2170	2196	2.0	1675.9	2214.5	132.6
2175	2188	4.6	2284.1	1487.1	581.8	2170	2171	1.6	1675.0	2320.5	135.0
2175	2197	.8	2284.1	1878.0	581.8	2001	2171	1.6	1675.0	2333.4	135.0
2176	2197	2.5	862.6	1586.2	396.2	2001	2181	4.7	1589.9	3202.1	1372.7
2176	2177	1.1	862.6	1575.9	396.2	2181	2191	4.4	0.0	1710.2	1476.2
2177	2198	3.0	862.6	1695.4	396.2	2179	2181	1.1	0.0	2504.7	2313.1
2178	2198	4.4	561.5	1009.6	533.6	2179	2180	1.1	0.0	3304.0	2313.1
2164	2178	6.0	561.5	2744.0	1070.7	2177	2180	.8	0.0	1873.4	2501.7
2164	2165	6.2	93.3	1906.2	19.7	2169	2172	2.9	0.0	2174.4	2501.7
2165	2166	3.8	93.3	1449.8	19.7	2169	2178	7.7	0.0	2004.7	2501.7
2166	2167	2.6	93.3	1007.7	41.6	2187	2192	7.3	0.0	1648.6	886.0
2167	2195	1.2	93.3	1007.7	41.6	2174	2187	.7	0.0	1648.6	886.9
2168	2195	1.7	84.0	2033.3	247.4	2174	2181	.6	0.0	2046.7	886.9
2128	2168	4.8	84.0	2033.3	247.4	2180	2196	6.5	0.0	2952.2	1962.4

TABLE A1 (CONTINUED)

NODE A	NODE B	DIST-ANCE	PHASE II	PHASE III	NODE A	NODE B	DIST-ANCE	PHASE II	PHASE III
US 6									
2369	2590	10.6	0.0	0.0	2580	2581	13.7	168.8	0.0
2096	2589	6.0	0.0	0.0	2579	2588	6.6	203.2	0.0
2151	2588	8.2	0.0	0.0	2578	2579	3.7	105.0	0.0
2587	2588	11.6	0.0	0.0	2577	2578	1.7	166.9	0.0
2586	2587	11.1	0.0	0.0	2530	2577	6.0	374.7	0.0
2585	2586	9.0	427.8	33.3	2530	2576	11.7	108.9	0.0
2264	2585	1.1	437.1	33.3	2534	2576	3.8	273.6	0.0
2263	2264	1.5	403.6	33.3	2574	2575	7.6	293.8	0.0
2263	2586	10.7	130.3	0.0	2573	2574	9.1	202.0	0.0
2591	2586	3.0	137.7	0.0	2122	2573	6.8	269.2	0.0
2409	2583	10.7	167.8	0.0	2122	2507	3.7	681.0	17.0
2284	2583	13.1	132.7	0.0	2507	2572	13.1	339.2	17.9
2284	2582	17.2	170.7	0.0	2572	4100	10.0	323.9	17.9
2581	2582	16.9	175.6	0.0					
US 17									
2156	2617	22.0	0.0	0.0	2608	2609	5.9	492.0	0.0
2612	2617	1.8	0.0	0.0	2608	2618	9.2	18.3	0.0
2611	2612	8.1	0.0	0.0	2618	4001	14.0	0.0	0.0
2609	2611	8.7	0.0	0.0					
US 30									
2158	2613	6.2	210.4	0.0	2598	2599	12.1	9.8	0.0
2159	2613	1.0	21.8	0.0	2597	2598	8.2	5.1	0.0
2159	2610	4.6	0.0	0.0	2596	2597	8.6	15.9	0.0
2609	2610	7.8	570.4	0.0	2595	2596	8.3	28.8	0.0
2607	2609	5.2	27.6	0.0	2594	2595	13.6	30.7	0.0
2606	2607	4.7	20.6	0.0	2593	2594	11.2	63.7	0.0
2162	2606	3.1	405.3	0.0	2592	2593	7.2	66.8	0.0
2162	2605	4.2	284.7	0.0	2126	2592	9.2	77.9	0.0
2604	2605	11.5	152.2	0.0	2126	2510	5.8	119.4	0.0
2603	2604	17.9	0.0	0.0	2510	2591	7.6	87.2	0.0
2602	2603	3.1	39.3	0.0	2590	2591	5.4	80.7	0.0
2287	2602	8.6	39.3	0.0	2590	4087	7.0	33.7	0.0
2287	2620	3.3	0.0	0.0	2603	2616	5.0	21.1	0.0
2619	2620	12.6	0.0	0.0	2615	2616	2.9	161.0	0.0
2601	2619	26.1	0.0	0.0	2614	2615	3.2	53.7	0.0
2600	2601	4.6	40.6	0.0	2286	2614	5.2	53.7	0.0
2599	2600	6.0	40.6	0.0					
US 24									
2241	4365	6.0	213.5	34.0	2539	2540	14.8	287.5	0.0
2240	2241	6.7	175.9	34.0	2538	2539	7.1	363.7	0.0
2240	2545	8.5	170.3	20.5	2537	2538	3.0	89.1	0.0
2403	2545	16.5	163.9	20.5	2537	2547	3.0	106.5	0.0
2080	2403	3.8	192.9	20.5	2547	2548	11.8	308.5	0.0
2080	2402	9.3	167.1	1.1	2116	2548	6.8	508.1	0.0
2254	2402	12.6	195.1	1.1	2116	2503	11.1	529.9	17.0
2253	2254	11.1	138.1	1.1	2503	2549	5.6	330.6	17.0
2253	2546	1.9	230.7	1.1	2549	2550	5.3	401.3	42.3
2482	2546	28.7	161.6	1.1	2550	2551	20.7	52.3	17.0
2481	2482	3.2	254.6	1.1	2551	4178	0.0	65.7	17.0
2276	2481	10.0	287.9	1.1	2562	2623	6.1	88.6	.3
2276	2543	6.0	869.6	1.1	2560	2623	7.2	152.1	0.0

TABLE A1 (CONTINUED)

2542	2543	14.1	369.0	0.0	2538	2544	4.1	254.6	0.0
2541	2542	7.2	270.6	0.0	2544	2547	1.4	254.6	0.0
2540	2541	3.7	281.8	0.0					
	UP	29							
2511	4187	22.0	170.2	25.5	2601	2602	30.7	304.4	32.2
2511	2512	10.0	425.8	25.5	2602	2603	3.8	349.4	32.2
2307	2512	12.8	410.8	25.5	2603	2674	8.9	374.8	0.0
2138	2307	6.0	67.0	0.0	2118	2674	4.9	426.1	0.0
2138	2200	10.8	241.7	0.0	2118	2604	10.3	73.5	0.0
2299	2403	14.1	276.0	0.0	2604	2605	8.0	33.9	0.0
2403	2404	8.8	163.3	0.0	2121	2505	3.8	228.3	0.0
2404	2405	17.4	165.7	0.0	2121	2506	3.4	363.4	0.0
2405	2406	4.9	174.6	0.0	2506	2507	10.7	44.7	0.0
2406	2407	4.8	285.7	0.0	2507	2508	11.2	18.3	0.0
2407	2408	4.3	151.4	0.0	2508	2509	2.9	56.6	0.0
2408	2409	9.7	71.0	0.0	2509	2510	7.6	56.6	0.0
2409	2500	9.8	88.4	0.0	2126	2510	11.6	114.0	0.0
2500	2501	10.3	84.8	0.0					
	UP	30							
2368	4384	9.0	460.8	65.3	2558	2559	17.4	860.0	62.5
2368	2571	10.3	122.5	65.3	2557	2558	13.7	580.1	62.5
2570	2571	1.9	122.5	54.3	2556	2557	5.3	700.0	62.5
2094	2570	1.1	122.5	65.3	2555	2556	9.4	469.7	47.0
2095	2560	6.1	307.4	28.7	2554	2555	1.5	396.7	77.9
2568	2569	13.3	307.4	28.7	2514	2554	17.6	416.1	62.5
2567	2568	3.9	418.0	28.7	2116	2514	1.2	566.3	62.5
2262	2567	9.1	376.1	28.7	2116	2624	9.8	0.0	0.0
2262	2566	10.3	632.8	62.0	2553	2624	3.3	217.6	30.3
2489	2566	7.4	651.3	62.0	2540	2553	6.7	140.8	30.3
2480	2565	7.5	748.4	67.0	2550	2552	18.9	0.0	0.0
2564	2565	9.2	726.9	62.0	2552	4130	12.0	104.7	30.3
2562	2564	7.5	100.4	0.0	2563	2564	3.6	626.5	62.0
2561	2562	11.3	0.0	0.0	2282	2563	2.3	643.3	62.0
2560	2561	6.3	620.4	62.0	2282	2561	4.1	620.4	62.0
2550	2560	6.0	565.9	62.0					
	UP	31							
2037	2330	8.9	0.0	0.0	2270	2271	12.0	1030.5	23.7
2035	2429	13.6	0.0	0.0	2271	2272	4.3	1176.4	23.7
2036	2331	6.9	567.4	60.3	2272	2273	17.9	606.7	23.7
2033	2331	.9	577.8	60.5	2273	2274	6.9	807.1	23.7
2033	2330	.5	466.8	0.0	2274	2275	1.5	828.0	23.7
2329	2330	2.7	217.9	0.0	2275	2276	6.5	868.8	23.7
2328	2329	12.7	0.0	0.0	2276	2277	9.8	521.6	23.7
2327	2328	10.6	0.0	0.0	2277	2278	21.3	512.3	23.7
2326	2327	6.8	1.7	0.0	2278	2279	11.4	545.6	23.7
2324	2326	7.0	98.3	0.0	2279	2280	6.2	573.5	23.7
2028	2325	5.5	0.0	0.0	2280	2281	6.0	563.6	23.7
2024	2324	8.9	0.0	0.0	2281	2282	4.3	663.6	23.7
2323	2324	11.0	0.0	0.0	2282	2283	7.3	440.7	23.7
2320	2323	10.9	298.9	0.0	2283	2284	1.6	549.5	23.7
2319	2320	9.1	76.7	0.0	2284	2285	7.6	478.8	23.7
2318	2319	8.1	35.6	0.0	2285	2286	6.8	457.0	23.7
2022	2318	8.7	35.6	0.0	2286	2287	15.6	403.3	23.7

TABLE A1 (CONTINUED)

2022	2312	3.9	202.7	0.0	2287	2288	3.0	1584.8	23.7
2316	2317	4.5	153.0	0.0	2146	2288	4.4	1044.0	123.5
2315	2316	8.4	137.9	0.0	2288	4006	9.0	663.9	147.2
2314	2315	11.4	50.8	0.0	2025	2444	10.4	0.0	0.0
2173	2314	15.1	0.0	0.0	2025	2322	14.8	143.0	0.0
2144	2265	5.0	1103.2	23.7	2321	2322	7.4	222.0	0.0
2265	2266	1.9	959.2	23.7	2318	2321	13.8	0.0	0.0
2266	2267	4.3	1003.2	23.7	2281	2542	7.4	100.0	0.0
2267	2268	4.4	953.1	23.7	2542	2543	4.4	145.6	0.0
2268	2269	3.1	990.3	23.7	2283	2543	8.3	178.9	0.0
2269	2270	12.0	1092.7	23.7					
	US	33							
2513	4133	6.0	284.6	32.2	2521	2522	11.9	0.0	0.0
2501	2513	14.2	247.1	32.2	2522	2523	1.0	144.8	0.0
2316	2501	12.5	0.0	0.0	2523	2524	5.5	136.7	0.0
2514	2515	14.0	150.2	0.0	2524	2525	15.0	158.7	0.0
2515	2516	11.3	144.9	0.0	2525	2526	22.6	210.0	0.0
2516	2517	6.1	117.8	0.0	2526	2527	7.0	10.6	0.0
2517	2518	6.6	224.3	0.0	2527	2528	7.1	25.0	0.0
2518	2519	5.8	207.3	0.0	2528	2529	17.2	5.4	0.0
2519	2520	7.2	290.7	0.0	2287	2529	8.4	81.1	0.0
2520	2521	.5	255.7	0.0					
	US	35							
2137	2462	1.7	1011.3	11.4	2272	2478	5.0	765.7	0.0
2462	2463	10.4	784.9	11.1	2478	2479	11.7	249.3	0.0
2297	2463	5.2	763.7	11.4	2479	2480	11.0	165.0	0.0
2297	2464	20.6	748.5	11.4	2480	2481	15.2	135.1	0.0
2464	2465	5.4	964.4	0.0	2482	2483	13.1	126.1	0.0
2465	2466	6.0	570.3	0.0	2483	2484	22.8	57.4	0.0
2466	2467	6.7	449.5	0.0	2484	2485	18.4	66.3	0.0
2467	2468	4.8	727.2	0.0	2485	2486	3.3	40.9	0.0
2468	2469	13.3	201.5	0.0	2486	2487	6.4	74.9	0.0
2469	2470	6.0	256.1	0.0	2487	2488	7.6	93.6	0.0
2470	2471	10.0	349.7	0.0	2488	2489	7.3	106.3	0.0
2471	2472	4.3	515.5	0.0	2489	2490	8.4	211.0	0.0
2472	2473	1.5	377.5	0.0	2490	2491	6.6	321.0	0.0
2473	2474	9.3	352.3	0.0	2491	2492	9.4	265.7	0.0
2474	2475	3.3	371.0	0.0	2162	2492	11.1	405.8	0.0
2475	2476	6.0	267.5	0.0	2606	2608	8.5	384.7	0.0
2476	2477	7.7	225.1	0.0	2141	4140	16.0	635.0	92.4
2272	2477	4.7	201.9	0.0					
	US	36							
2300	4158	21.0	125.6	48.4	2138	2280	12.7	66.1	0.0
2299	2300	10.3	74.1	0.0	2137	2210	12.6	77.7	0.0
2298	2299	13.6	93.5	0.0	2210	2211	14.8	85.3	0.0
2297	2298	5.6	120.0	0.0	2211	2212	11.9	49.1	0.0
2296	2297	13.2	112.4	0.0	2212	2213	18.9	17.7	0.0
2295	2296	2.5	148.5	0.0	2213	2214	16.7	71.7	0.0
2294	2295	21.8	47.0	0.0	2214	2215	13.7	110.1	0.0
2293	2294	1.4	414.0	0.0	2215	2216	12.9	92.9	0.0
2292	2293	6.8	40.7	0.0	2216	2217	1.2	456.7	0.0
2291	2292	.5	450.3	47.2	2217	2218	6.5	66.6	0.0
2290	2291	10.2	95.5	0.0	2218	4349	13.0	64.7	0.0

TABLE A1 (CONTINUED)

2289	2290	5.9	89.0	0.0					
US	40								
2140	2307	7.8	586.0	0.0	2201	2202	5.3	177.6	0.0
2307	2622	20.8	30.8	0.0	2202	2203	13.0	97.1	0.0
2306	2622	3.0	273.0	0.0	2203	2204	10.9	46.2	0.0
2305	2306	13.2	91.4	0.0	2204	2205	3.4	260.5	0.0
2304	2305	5.5	132.0	0.0	2205	2206	17.5	260.5	0.0
2303	2304	7.3	141.1	0.0	2206	2207	8.3	166.3	0.0
2302	2303	10.4	83.1	0.0	2207	2208	14.0	104.6	0.0
2301	2302	6.3	137.7	0.0	2208	2209	7.8	160.1	0.0
2170	2301	16.5	280.7	0.0	2065	2209	21.0	14.7	0.0
2176	2201	17.6	265.8	0.0					
US	41								
2621	4288	10.0	495.6	166.3	2351	2352	6.9	116.6	0.0
2332	2621	8.7	480.2	166.3	2225	2352	7.4	95.2	0.0
2332	2333	6.0	798.1	166.3	2073	2225	2.1	234.4	0.0
2050	2333	11.0	406.9	132.9	2073	2353	10.3	215.5	26.7
2050	2334	1.1	563.8	87.0	2353	2354	7.2	235.6	26.7
2334	2335	5.1	538.7	87.0	2354	2355	3.5	245.4	26.7
2335	2336	9.4	470.8	87.0	2355	2356	2.0	209.6	26.7
2336	2337	10.7	291.8	.9	2356	2357	6.4	122.5	26.7
2337	2338	4.8	291.3	.9	2357	2358	6.2	375.0	54.6
2338	2339	22.6	268.5	.9	2358	2359	7.3	365.8	37.8
2339	2340	3.7	337.1	.9	2359	2360	10.1	323.6	37.8
2340	2341	11.1	265.3	.9	2239	2360	3.6	271.9	37.8
2341	2342	17.9	292.8	.9	2239	2240	12.5	303.6	37.8
2342	2343	8.5	340.7	.9	2240	2361	8.2	375.0	51.2
2343	2344	7.0	346.2	.9	2361	2362	6.2	374.1	51.2
2344	2345	6.6	286.8	.9	2362	2363	6.4	379.9	51.2
2345	2346	12.3	398.6	.9	2363	2364	10.9	345.7	51.2
2346	2347	8.1	403.6	.9	2364	2365	9.2	258.9	0.0
2063	2347	13.8	584.4	.9	2365	2366	3.2	319.0	0.0
2063	2208	4.8	930.4	0.0	2366	2367	11.7	218.2	0.0
2208	2348	21.5	255.0	0.0	2367	2368	8.3	330.1	0.0
2215	2348	15.9	124.8	0.0	2368	2369	9.2	17.4	0.0
2215	2349	10.8	138.2	0.0	2154	2369	7.9	17.4	0.0
2349	2350	2.8	163.2	0.0	2154	2157	11.7	0.0	0.0
2350	2351	9.0	103.7	0.0					
US	50								
2339	4328	14.0	187.7	0.0	2445	2446	20.1	34.7	0.0
2340	4328	12.0	222.5	0.0	2026	2446	3.4	425.5	0.0
2340	2439	16.3	141.2	0.0	2026	2323	.6	410.3	0.0
2438	2439	11.8	228.7	0.0	2323	2447	17.4	119.4	0.0
2381	2438	22.3	146.5	0.0	2447	2448	30.0	87.8	0.0
2381	2437	11.4	134.4	0.0	2448	2449	3.8	132.2	0.0
2436	2437	6.0	57.9	0.0	2449	2450	11.0	96.7	0.0
2436	2440	15.0	44.4	0.0	2450	2451	7.3	97.4	0.0
2440	2441	13.0	14.7	0.0	2451	2452	13.6	142.6	0.0
2441	2442	10.0	131.2	0.0	2452	2453	0.9	400.3	0.0
2442	2443	24.8	318.3	0.0	2453	2454	3.2	679.4	0.0
2443	2444	3.5	307.6	0.0	2186	2454	2.0	653.8	0.0
2444	2445	6.2	230.7	0.0	1769	2454	16.0	0.0	0.0
US	52								

TABLE A1 (CONTINUED)

2238	2239	6.6	68.4	0.0	2227	2228	14.5	6.0	0.0
2237	2238	7.0	151.2	0.0	2080	2227	6.3	115.8	0.0
2236	2237	6.0	80.8	0.0	2171	2308	24.8	17.7	0.0
2235	2236	4.6	74.1	0.0	2308	2309	28.8	17.6	0.0
2234	2235	11.5	87.6	0.0	2309	2428	17.0	31.0	0.0
2233	2234	7.3	87.6	0.0	2310	2428	0.4	68.6	0.0
2232	2233	6.2	78.1	0.0	2310	2311	2.2	89.7	0.0
2231	2232	3.6	171.8	0.0	2311	2312	12.6	90.5	0.0
2230	2231	8.5	0.0	0.0	2312	2313	12.2	164.7	0.0
2229	2230	4.1	83.2	0.0	2018	2313	10.4	189.2	0.0
2228	2229	20.2	0.0	0.0					
UC	234								
2226	4351	17.0	0.0	0.0	2221	2222	31.8	0.0	0.0
2225	2226	23.5	0.0	0.0	2220	2221	9.1	16.8	0.0
2224	2225	10.0	27.7	0.0	2219	2220	18.0	0.0	0.0
2223	2224	9.2	26.6	0.0	2198	2219	14.7	0.0	0.0
2222	2223	17.1	16.8	0.0	0	0	0.0	0.0	0.0
UC	150								
2209	4350	20.0	67.3	0.0	2432	2433	26.8	56.6	0.0
2435	2436	6.6	8.1	0.0	2431	2432	15.7	8.2	0.0
2434	2435	16.8	67.5	0.0	2430	2431	9.0	16.7	0.0
2433	2434	16.6	93.9	0.0	2429	2430	36.6	0.0	0.0
UC	226								
2536	2537	3.6	610.8	0.0	2531	2532	6.0	109.1	20.9
2112	2536	9.2	152.3	0.0	2601	2531	13.1	188.9	20.9
2112	2534	2.6	490.2	20.9	2601	2530	0.6	178.9	20.9
2533	2534	6.7	653.7	20.9	2530	4131	12.0	155.0	20.9
2532	2533	9.0	317.7	20.9	0	0	0.0	0.0	0.0
UC	231								
2370	4370	10.0	300.1	147.0	2059	2304	6.5	567.3	0.0
2370	2371	6.0	300.1	153.0	2304	2398	8.1	361.0	1.0
2371	2372	6.3	105.6	67.6	2213	2398	14.6	305.5	0.0
2372	2373	9.0	52.5	0.0	2213	2396	9.0	154.8	0.0
2373	2374	6.3	49.0	0.0	2396	2397	7.4	172.5	0.0
2374	2375	7.1	59.5	0.0	2222	2397	14.4	149.0	0.0
2375	2376	6.8	58.7	0.0	2071	2222	6.2	285.6	0.0
2376	2377	2.8	63.3	0.0	2071	2398	19.7	166.9	0.0
2046	2377	3.6	38.4	0.0	2398	2399	13.3	136.2	0.0
2046	2378	13.7	126.2	0.0	2399	2400	6.0	251.2	0.0
2378	2379	14.6	115.4	0.0	2232	2400	7.1	371.2	0.0
2379	2380	14.0	104.7	0.0	2236	2401	17.2	32.0	0.0
2380	2381	18.7	94.7	0.0	2088	2401	5.9	31.0	0.0
2381	2382	17.0	125.7	0.0	2088	2402	7.6	43.8	0.0
2382	2383	3.7	125.7	0.0	2090	2403	4.6	66.8	0.0
2383	2384	6.3	181.5	0.0	2090	2404	5.3	143.8	0.0
2384	2385	1.8	180.4	0.0	2404	2405	9.1	117.1	0.0
2385	2386	12.1	40.7	0.0	2405	2406	11.4	76.5	0.0
2386	2387	7.3	83.3	0.0	2406	2407	10.8	50.6	0.0
2387	2388	4.6	99.4	0.0	2407	2408	4.1	6.0	0.0
2388	2389	11.3	174.9	0.0	2408	2409	3.0	165.7	.5
2389	2390	23.5	172.7	0.0	2409	2410	9.7	76.6	0.0
2390	2391	3.6	333.3	0.0	2410	2411	4.8	166.8	0.0
2391	2392	9.4	247.8	0.0	2006	2411	19.9	0.0	0.0

TABLE A3 (CONTINUED)

2392	2393	14.6	234.5	0.0	2096	2417	4.3	480.9	0.0
2393	2394	3.3	235.8	0.0	2367	2417	11.0	167.9	0.0
2050	2394	3.0	280.4	0.0					
US 421									
2455	4268	3.0	247.1	0.0	2250	2251	7.0	97.8	0.0
2455	2456	10.0	16.8	0.0	2251	2252	4.8	146.7	0.0
2456	2457	11.0	46.4	0.0	2252	2253	16.7	80.1	0.0
2440	2457	26.3	20.7	0.0	2254	2255	15.2	87.0	0.0
2448	2458	10.4	83.0	0.0	2255	2256	7.6	106.1	0.0
2458	2459	3.7	93.5	0.0	2256	2257	9.2	57.9	0.0
2459	2460	20.7	76.1	0.0	2257	2258	7.7	147.5	0.0
2008	2460	17.4	0.0	0.0	2258	2259	13.9	38.9	0.0
2168	2242	.9	374.9	0.0	2259	2260	2.7	160.8	.8
2242	2243	8.6	190.5	0.0	2260	2261	12.1	53.7	0.0
2243	2244	8.7	222.3	0.0	2261	2262	11.6	69.7	0.0
2244	2245	8.0	241.4	0.0	2262	2263	7.9	377.4	33.3
2245	2246	9.6	190.7	0.0	2264	2461	4.8	52.6	0.0
2246	2247	11.6	123.5	0.0	2148	2461	3.0	136.6	0.0
2247	2248	11.2	49.5	0.0	2148	2161	5.3	125.8	0.0
2248	2249	7.5	54.3	0.0	2161	2607	2.6	21.2	0.0
2249	2250	9.4	51.9	0.0	2607	2608	8.3	14.2	0.0
US 460									
2413	4319	12.0	72.5	0.0	2420	2421	11.4	16.0	0.0
2413	2414	13.2	0.0	0.0	2421	2422	8.3	0.0	0.0
2414	2415	15.4	0.0	0.0	2422	2423	9.4	81.9	0.0
2415	2538	14.0	0.0	0.0	2423	2424	10.3	0.0	0.0
2332	2535	7.1	150.5	0.0	2424	2425	13.0	0.0	0.0
2332	2416	34.0	14.2	0.0	2425	2426	14.4	0.0	0.0
2416	2417	8.3	96.6	74.8	2426	2427	22.5	0.0	0.0
2417	2418	4.9	28.7	0.0	2427	2428	3.4	0.0	0.0
2376	2418	5.1	21.2	0.0	2058	2428	13.4	0.0	0.0
2377	2419	11.6	3.6	0.0	2055	2429	6.1	223.7	0.0
2419	2420	5.4	61.9	0.0	2185	2429	9.7	1355.4	0.0
IND 1									
3071	4035	5.0	35.9	0.0	3126	3127	8.0	164.0	0.0
2590	3071	8.4	17.0	0.0	3127	3128	13.6	78.7	0.0
2591	3030	9.6	42.5	0.0	2208	3128	13.9	115.8	0.0
2572	3030	14.7	24.6	0.0	2208	2463	7.5	80.6	0.0
2572	3068	8.1	147.1	0.0	2463	3130	10.4	87.4	0.0
2119	3068	30.0	0.0	0.0	2306	3130	12.5	103.8	0.0
2832	3065	21.2	12.4	0.0	2306	3188	30.2	89.8	0.0
2832	3104	8.5	32.3	0.0	2312	3188	27.9	93.4	0.0
3104	3108	10.0	102.1	0.0	2313	3191	13.6	5.6	0.0
3108	3115	9.6	183.7	0.0	2014	3191	1.2	5.6	0.0
3115	3116	8.4	132.7	0.0	2014	2453	27.8	80.0	0.0
3116	3118	3.7	250.9	0.0	2135	2422	5.0	241.2	0.0
3118	3126	9.1	174.0	0.0					
IND 2									
2365	4375	13.0	106.2	0.0	2586	3036	13.7	56.8	0.0
2366	3007	18.4	.5	0.0	2461	2586	4.7	47.5	0.0
2093	3007	4.7	90.4	0.0	2461	2492	16.8	20.8	0.0
2093	2410	6.4	215.5	0.0	2492	2606	14.0	78.2	0.0
2411	2568	18.5	110.7	0.0	2606	2616	15.4	105.1	0.0

TABLE A1 (CONTINUED)

2567	3035	2.0	208.2	0.0	2287	2616	9.3	226.0	0.0
IND 5									
3063	4024	9.0	1.9	0.0	2295	3131	6.3	318.5	0.0
2593	3083	9.4	71.0	0.0	2133	3131	13.7	377.8	0.0
2574	2593	20.0	70.6	0.0	2133	2306	7.7	182.2	0.0
2574	3086	8.4	121.0	0.0	2306	2309	21.4	277.1	0.0
3086	3087	3.7	133.1	0.0	2309	3189	11.4	274.7	0.0
3069	3087	9.5	118.8	0.0	2010	3189	12.5	287.9	0.0
2117	3069	15.4	107.5	0.0	2010	2440	3.3	374.5	0.0
2117	2674	5.0	168.2	30.3	2440	3198	10.6	447.0	0.0
2567	3065	12.4	33.2	0.0	2447	3198	37.4	16.5	0.0
3064	3065	17.7	0.0	0.0	2447	3219	22.4	67.9	0.0
2534	3064	13.8	-0.0	0.0	3218	3219	9.6	67.9	0.0
2534	3102	15.9	1.7	0.0	3217	3218	4.4	0.0	0.0
3102	3110	8.0	84.6	0.0	3217	3220	2.5	0.0	0.0
3110	3113	9.4	84.4	0.0	3220	3221	3.3	0.0	0.0
3113	3121	13.4	87.2	0.0	3215	3221	6.3	1.7	0.0
2467	3121	19.0	100.5	0.0	3214	3215	20.5	0.0	0.0
2295	2464	16.5	214.4	0.0					
IND 6									
2594	3081	8.4	104.0	0.0	3059	3060	4.6	242.1	0.0
2521	2594	19.9	95.8	0.0	3058	3059	3.3	262.1	0.0
2519	3075	7.1	34.6	0.0	2537	3058	7.7	305.5	0.0
2556	3075	20.9	57.9	0.0	2536	3101	11.5	467.5	0.0
2556	3054	12.5	296.1	0.0	2111	3101	2.1	619.0	.2
3054	3060	9.3	227.2	0.0	2111	3111	5.8	99.7	.3
IND 8									
2411	3011	18.0	11.9	0.0	3074	3075	3.2	69.8	0.0
2261	3011	16.0	4.0	0.0	2518	3075	6.3	17.0	0.0
2261	3018	13.7	11.2	0.0	3085	3086	14.4	12.1	0.0
2488	3018	8.1	19.5	0.0	2505	3087	7.9	56.8	0.0
2487	3030	9.7	61.2	0.0	2506	3068	21.6	50.3	0.0
3029	3030	7.6	25.5	0.0	3068	4104	10.0	149.0	0.0
3073	3074	2.8	63.9	0.0					
IND 9									
2143	4023	4.0	218.9	111.1	2472	3092	9.4	236.8	0.0
2143	3082	3.1	263.0	0.0	2472	3158	8.3	104.0	0.0
2594	3082	9.7	135.8	0.0	3148	3158	13.6	181.6	0.0
2578	2594	26.2	8.5	0.0	3147	3148	11.8	266.4	0.0
2576	3085	7.1	84.4	0.0	3145	3147	14.5	241.1	0.0
2516	3085	11.1	69.7	0.0	2101	3145	16.9	576.4	0.0
2516	2555	12.5	32.9	0.0	2291	3136	7.9	354.8	42.2
2555	3063	3.4	231.3	0.0	2131	3136	7.1	624.9	42.2
3061	3063	9.8	180.9	0.0	2131	2301	6.0	528.2	42.2
3061	3062	4.8	163.4	0.0	2301	2308	11.3	466.5	42.2
2537	3062	12.1	157.0	0.0	2006	2308	13.3	627.3	42.2
2537	3097	18.5	27.9	0.0	2006	3190	6.6	302.5	0.0
3097	3098	7.8	25.3	0.0	3190	3199	31.8	70.3	0.0
3092	3098	14.6	65.4	0.0	2320	3199	9.6	295.9	0.0
IND 10									
2364	4376	16.0	300.4	74.4	3016	3017	2.7	193.4	.5
2364	3006	7.0	483.9	125.7	2486	3017	8.1	142.2	.5
2092	3006	4.9	485.8	125.7	2485	3027	3.5	23.4	0.0

TABLE A1 (CONTINUED)

2092	3010	4.4	173.5	.5	3027	3028	3.3	136.6	.5
2409	3010	4.0	131.8	.5	3026	3028	7.9	135.5	.5
2408	3009	7.4	158.7	.5	2280	3026	7.9	175.0	.5
2259	3009	10.7	122.7	.5	2280	3043	15.0	68.6	.5
2260	3016	8.1	116.4	.5	3043	3044	4.5	215.9	.5
	IND	13							
2144	4016	5.0	327.0	87.1	3091	3093	15.2	91.5	0.0
2144	3080	2.7	335.9	0.0	2474	3091	11.0	85.6	0.0
2536	3080	9.8	196.5	0.0	2474	3156	5.3	107.9	0.0
2596	3077	4.8	252.0	0.0	3151	3156	16.8	120.2	0.0
2522	3077	15.2	77.8	0.0	3149	3151	9.0	249.9	0.0
2523	2578	1.4	28.1	0.0	3143	3149	14.1	65.0	0.0
2579	3073	11.8	13.6	0.0	3143	3144	7.0	18.7	0.0
2557	3073	18.3	67.8	0.0	2099	3144	2.0	92.3	0.0
2557	3053	17.9	26.3	0.0	2099	2290	10.4	76.2	0.0
3051	3053	9.4	94.0	0.0	2290	3137	3.7	293.6	0.0
3050	3051	8.1	130.3	0.0	2301	3137	13.6	78.4	0.0
2540	3050	7.7	108.6	0.0	2522	2577	1.3	220.0	0.0
2623	3093	12.8	76.2	0.0	2577	3074	7.4	62.2	0.0
	IND	14							
2363	3005	8.1	34.2	0.0	3040	3041	12.5	112.6	0.0
2406	3005	14.0	34.2	0.0	3041	3046	14.3	31.0	0.0
2406	3008	8.7	93.5	0.0	3046	3053	11.8	15.9	0.0
2257	3008	8.4	101.3	0.0	3053	3054	8.5	88.3	0.0
2258	3015	4.4	131.1	0.0	3054	3061	11.6	29.6	0.0
2484	3015	16.2	70.0	0.0	2115	3061	16.9	47.0	0.0
2484	3023	17.2	55.1	0.0	2115	2503	8.0	318.2	32.2
2278	3023	16.6	44.9	0.0	2550	3066	12.3	269.3	30.3
2278	3040	4.0	203.7	0.0	3066	4129	17.0	62.0	0.0
	IND	15							
3079	4015	8.0	136.0	0.0	3068	3069	6.4	153.7	0.0
2597	3079	7.6	145.9	0.0	2541	3069	3.8	153.7	0.0
2525	2597	9.6	135.1	0.0	2541	2623	4.3	142.5	0.0
2525	2580	16.5	106.6	0.0	2623	3094	12.2	166.8	0.0
2558	2580	23.6	121.9	0.0	3094	3095	8.4	247.6	0.0
2558	3046	19.5	170.5	0.0	3092	3095	14.0	119.2	0.0
3046	3047	7.5	184.1	0.0	2471	3092	15.2	0.0	0.0
3047	3048	8.0	302.3	0.0					
	IND	16							
2361	3001	3.7	31.0	0.0	2483	3019	10.3	56.1	0.0
3001	3002	7.8	0.0	0.0	3019	3020	4.3	137.6	0.0
2404	3003	10.6	54.8	0.0	2277	3020	12.3	51.7	0.0
2255	2404	20.3	53.0	0.0	2277	3038	8.9	35.6	0.0
2255	3012	9.8	61.5	0.0	3039	3048	9.7	140.6	0.0
3012	3013	2.3	102.2	0.0	3048	3050	6.8	40.8	0.0
3013	3014	6.1	97.7	0.0	3050	3057	11.5	62.4	0.0
2483	3014	17.9	80.3	0.0	3057	3058	4.5	43.3	0.0
	IND	18							
3159	4364	18.0	71.1	0.0	2273	3089	14.7	142.7	0.0
2360	3159	7.6	32.7	0.0	3089	3090	4.0	216.6	0.0
2238	2360	7.6	61.5	0.0	3090	3091	5.0	101.0	0.0
2237	2401	19.4	71.0	0.0	3091	3092	16.4	40.0	0.0
2087	2401	3.6	22.0	0.0	2109	3092	13.4	327.3	0.0

TABLE 21 (CONTINUED)

2087	3160	8.4	113.7	0.0	2109	3112	3.7	342.4	24.1
2252	3169	12.0	96.5	0.0	3112	3113	9.4	234.1	24.1
2250	3171	11.1	43.0	0.0	3113	3114	8.4	230.0	24.1
3171	3175	9.9	83.0	0.0	3114	3115	9.9	181.9	24.1
2479	3175	17.1	65.9	0.0	2497	3115	13.6	232.9	24.1
2273	2479	5.6	201.1	0.0					
IND	19								
2145	4016	4.0	161.2	175.5	3041	3045	15.7	300.4	0.0
2148	2599	8.5	705.3	0.0	3039	3041	13.6	98.6	0.0
2527	2599	10.0	74.7	0.0	3038	3039	4.3	247.4	0.0
2527	3078	19.6	70.5	0.0	2543	3038	9.7	230.5	0.0
2581	3078	7.8	264.7	0.0	2437	3156	5.3	46.7	0.0
2559	2581	21.5	163.2	0.0	3153	3156	15.7	40.6	0.0
2559	3044	4.0	188.5	.5	3140	3153	32.2	8.0	0.0
3044	3045	8.3	204.4	0.0					
IND	24								
2228	3228	5.3	4.1	0.0	2251	3186	31.3	140.2	0.0
2072	2228	3.4	77.3	0.0	2481	3186	4.1	135.6	0.0
2072	3167	2.7	223.7	0.0	2481	3020	20.1	0.0	0.0
3166	3167	10.7	181.5	0.0	3020	3021	8.8	105.7	0.0
2399	3166	18.9	215.6	0.0	2278	3021	14.3	105.3	0.0
2229	2399	8.6	98.7	0.0	3040	3042	12.8	91.1	0.0
2085	2231	1.9	121.8	0.0	3042	3048	6.6	33.4	0.0
2085	2251	18.1	181.7	0.0	2558	3045	20.9	33.9	0.0
IND	26								
2358	4361	21.0	137.1	38.3	3155	3156	9.3	463.6	4.2
2358	3163	11.0	59.0	1.6	3156	3157	6.3	408.5	4.2
3163	3164	24.8	57.9	1.6	3157	3158	4.5	290.8	4.2
2400	3164	4.9	67.4	1.5	2107	3158	12.0	190.5	4.2
2230	2400	7.5	407.5	1.6	2107	2470	1.9	388.7	0.0
2084	2230	2.5	490.7	1.6	2470	3174	7.1	247.9	0.0
2084	2249	17.8	383.3	4.1	3121	3122	11.2	250.0	0.0
2249	3172	6.8	415.1	4.2	3120	3121	11.0	67.0	0.0
3172	3177	9.5	535.1	4.2	3119	3120	5.0	132.3	0.0
2271	3177	18.9	479.1	4.2	3118	3119	4.3	103.6	0.0
2271	3154	6.8	357.6	4.2	2406	3118	16.7	36.0	0.0
3154	3155	5.3	449.9	4.2	2495	4154	17.0	33.4	0.0
IND	28								
3161	4358	22.0	10.6	0.0	3151	3152	11.1	199.7	0.0
2356	3161	9.3	16.3	0.0	3150	3151	5.2	342.7	0.0
2356	3165	9.2	50.7	0.0	3148	3150	10.6	403.4	0.0
3165	3166	5.7	60.7	0.0	2106	3148	8.1	446.0	0.0
2398	3166	15.1	26.7	0.0	2106	2468	8.7	432.6	0.0
2228	2398	14.6	85.5	0.0	2467	3128	11.2	378.6	0.0
2082	2228	3.5	140.0	0.0	3125	3127	9.0	212.4	0.0
2082	2267	16.3	246.4	0.0	2494	3127	14.8	268.1	0.0
2246	2270	19.7	121.5	0.0	2494	3129	17.1	285.4	0.0
2270	3153	7.8	329.3	0.0	3129	4158	17.0	333.8	0.0
3152	3153	7.6	236.9	0.0					
IND	32								
2193	3222	15.0	266.0	0.0	2267	3140	12.0	64.0	0.0
2352	3222	18.3	.9	0.0	3140	3141	3.1	107.5	0.0
2352	3226	6.2	18.6	0.0	3141	3143	9.8	58.5	0.0

TABLE A1 (CONTINUED)

3225	3226	4.4	7.2	0.0	3143	3145	24.4	30.4	0.0
3227	3228	15.8	1.1	0.0	3145	3146	12.4	59.0	0.0
2070	2222	10.2	219.6	0.0	2104	3146	11.6	46.0	0.0
2030	3183	14.4	483.7	18.3	2104	2465	25.8	0.0	0.0
2079	3183	9.6	471.3	18.3	2465	3128	22.9	107.8	0.0
2079	3180	4.2	150.0	0.0	2493	3128	17.9	63.7	0.0
2243	3180	17.2	32.0	0.0	2493	3129	12.8	136.0	0.0
2243	2267	10.9	59.1	0.0	3129	4155	20.0	123.3	0.0
IND 37									
3307	3308	13.5	0.0	0.0	3244	3249	17.8	202.4	0.0
3311	4276	4.0	81.2	0.0	2188	3244	14.7	135.4	0.0
3308	3311	18.6	1.4	0.0	2097	2188	10.7	0.0	0.0
3308	3309	8.2	81.9	0.0	2097	3139	4.4	781.0	0.0
2422	3309	16.6	81.9	0.0	3139	3141	2.2	539.5	0.0
2042	2423	1.2	107.7	0.0	3141	3142	9.2	586.5	0.0
2042	3321	17.1	5.3	0.0	3142	3149	11.9	649.1	0.0
2433	3321	25.7	45.5	0.0	3149	3150	4.8	278.1	0.0
2433	3331	13.7	66.8	0.0	3150	3157	15.6	217.4	0.0
3331	3332	9.2	98.8	0.0	2473	3157	6.1	335.2	0.0
2441	3332	8.8	116.3	0.0	2473	3092	9.7	310.0	0.0
2442	3257	42.5	80.9	0.0	2503	2553	11.7	13.2	0.0
3257	3258	7.0	477.9	0.0	2553	3067	27.2	42.8	0.0
3249	3258	40.0	23.2	0.0	3067	4106	10.0	90.7	0.0
3250	3258	36.5	332.9	0.0	2195	3140	15.1	0.0	0.0
IND 38									
2083	2229	5.6	15.4	0.0	2100	3144	5.3	69.8	0.0
2083	2248	20.6	0.0	0.0	2100	2292	6.8	89.1	0.0
2245	3178	12.0	24.3	0.0	2292	3136	7.6	141.3	0.0
2245	3181	19.4	0.0	0.0	3132	3136	15.9	63.3	0.0
2268	3181	6.7	187.8	0.0	3131	3132	6.6	100.6	0.0
2268	3140	9.9	220.1	0.0	3130	3131	19.0	41.7	0.0
3141	3144	11.1	0.0	0.0	2467	3130	10.2	212.2	0.0
IND 39									
2163	2605	8.0	294.1	0.0	2078	3180	3.7	336.3	0.0
2147	2605	1.5	419.5	0.0	2068	2078	14.9	78.8	0.0
2147	2492	7.6	351.2	0.0	2068	2220	2.4	151.1	0.0
2492	2584	12.1	47.6	0.0	2211	2220	13.7	110.0	0.0
2566	2584	10.3	46.0	0.0	2202	2211	15.1	49.6	0.0
2566	3018	11.1	37.9	0.0	2057	2202	5.1	186.4	0.0
3017	3018	9.5	51.3	0.0	2057	3261	3.9	102.2	0.0
3015	3016	16.0	91.3	0.0	3261	3251	9.2	69.0	0.0
3012	3015	17.7	40.7	0.0	3250	3251	7.4	70.3	0.0
2544	3013	12.2	80.4	0.0	3249	3250	14.2	74.8	0.0
2247	3178	7.8	325.6	0.0	3336	3338	12.6	0.0	0.0
3178	3179	9.7	331.2	0.0	3336	3336	7.5	0.0	0.0
3179	3180	11.2	20.7	0.0	0	0	0.0	0.0	0.0
IND 46									
2062	3236	3.1	0.0	0.0	2023	2321	6.0	400.1	0.0
2062	3238	5.1	0.0	0.0	2319	2321	6.8	35.7	0.0
3237	3238	16.8	0.0	0.0	2319	3190	12.1	108.6	0.0
2390	3237	28.4	113.8	0.0	3198	3190	17.6	166.8	0.0
2391	3258	22.5	86.0	0.0	2460	3193	21.5	0.0	0.0
3256	3258	9.9	0.0	0.0	3192	3193	14.9	0.0	0.0

TABLE A3 (CONTINUED)

3254	3256	27.0	165.5	0.0	3191	3192	11.7	0.0	0.0
3253	3254	6.2	319.9	0.0	2015	3191	10.3	0.0	0.0
2023	3253	13.6	314.4	0.0					
IND 47									
2269	3181	5.9	102.3	0.0	2227	3182	4.8	192.6	0.0
2244	3181	10.7	168.4	0.0	2222	3182	31.4	35.7	0.0
2244	3179	10.9	220.9	0.0	2222	3228	15.5	49.7	0.0
2081	3179	7.9	492.9	7.5	3228	3229	7.0	93.1	0.0
2081	2227	7.8	91.7	0.0	2350	3229	14.0	73.0	0.0
IND 55									
2571	2580	17.6	0.0	0.0	2238	2565	15.8	86.0	0.0
2417	2571	10.4	0.0	0.0	2236	3162	6.6	56.7	0.0
2412	3007	16.7	0.0	0.0	3162	3163	8.0	46.8	0.0
3006	3007	15.3	0.0	0.0	2355	3163	14.8	49.7	0.0
3005	3006	12.1	1.1	0.0	2353	3168	9.5	20.1	0.0
3004	3005	11.0	1.1	0.0	3167	3168	7.9	26.6	0.0
3002	3004	7.7	81.1	0.0	2222	3167	23.3	0.0	0.0
2646	3002	10.2	104.0	0.0					
IND 56									
2337	3303	16.2	1.9	0.0	2030	2326	2.2	173.7	0.0
3302	3303	12.5	15.8	0.0	2326	3220	8.6	0.0	0.0
3301	3302	7.3	60.2	0.0	3212	3217	10.9	0.0	0.0
3300	3301	12.5	5.0	0.0	3212	3218	12.1	68.3	0.0
2378	3300	14.4	129.6	0.0	2455	3203	31.3	41.9	0.0
2380	2434	35.6	3.8	0.0	3203	3206	14.8	33.1	0.0
2433	3330	14.9	53.6	0.0	3201	3206	12.3	53.1	0.0
3329	3330	20.5	67.9	0.0	3200	3201	6.6	33.1	0.0
3329	3336	21.6	103.4	0.0	2452	3200	17.9	107.8	0.0
2030	3336	7.3	103.4	0.0					
IND 49									
3266	3269	10.9	55.1	0.0	2061	3237	.8	323.8	0.0
3269	3271	16.0	90.3	0.0	2061	2206	9.0	115.9	0.0
3271	3273	19.8	166.0	0.0	2206	2216	25.4	68.9	0.0
3273	3275	17.4	143.1	0.0	2216	3233	8.6	46.3	0.0
3275	3277	17.5	210.1	0.0	3229	3230	7.1	73.1	0.0
3237	3277	6.5	323.9	0.0					
IND 62									
3287	4318	38.0	79.3	0.0	3211	3212	10.0	15.3	0.0
2535	3287	22.1	150.5	0.0	2455	3211	8.4	367.2	0.0
2188	3216	29.0	0.0	0.0	2455	3206	20.1	12.6	0.0
3213	3216	20.2	11.5	0.0	3206	3207	15.6	38.3	0.0
3212	3213	9.2	36.6	0.0	2451	3208	16.9	38.7	0.0
IND 63									
2357	3161	7.6	252.5	27.9	2348	3235	9.6	5.8	0.0
2226	3161	16.0	260.1	27.9	3236	3235	5.7	335.5	0.0
2075	2226	7.8	263.7	27.9	2208	3236	19.9	281.3	0.0
2075	3222	6.3	322.7	0.0	2208	3279	24.9	2.5	0.0
3222	3223	9.3	466.2	0.0	3279	3280	7.4	9.6	0.0
3223	3224	5.1	463.0	0.0	3280	3281	8.3	10.6	0.0
2217	3224	10.9	374.6	0.0	3281	3283	7.6	33.7	0.0
2216	3235	7.9	341.4	0.0					
IND 64									
3243	4327	10.0	165.3	86.0	3318	3319	16.3	12.0	0.0

TABLE A1 (CONTINUED)

2336	3283	6.4	173.5	66.0	3319	3320	5.4	52.9	0.0
2336	3295	3.6	331.3	0.0	3320	3321	12.5	43.2	0.0
3295	3296	17.8	29.8	0.0	3321	3322	10.3	19.1	0.0
3296	3297	12.0	39.6	0.0	3322	3323	6.9	46.3	0.0
3297	3298	8.5	40.6	0.0	3323	3324	5.6	62.6	0.0
3298	3299	7.3	63.7	0.0	3324	3325	9.3	67.4	0.0
2378	3300	4.9	47.4	0.0	2030	3325	18.5	89.2	0.0
2378	3318	6.5	73.6	0.0	2030	2428	1.0	0.0	0.0
IND	66								
2621	3289	21.9	12.7	0.0	3310	3311	26.9	20.8	0.0
3289	3290	11.1	0.0	0.0	2423	3310	24.6	20.8	0.0
2371	3290	12.9	17.2	0.0	2041	2424	3.1	28.2	0.0
2372	3307	26.6	12.4	0.0	2041	3322	13.6	14.9	0.0
3307	3311	16.6	39.3	0.0	2432	3323	9.4	56.3	0.0
IND	67								
2340	3265	10.3	153.2	0.0	2175	3243	11.2	592.0	0.0
3264	3265	10.1	170.9	0.0	2101	2292	5.5	388.6	42.2
3264	3267	16.6	90.7	0.0	2103	2666	16.8	856.4	11.4
3267	3268	3.6	95.6	0.0	2666	3125	14.8	120.7	0.0
3269	3270	19.2	23.4	0.0	3125	3126	11.9	145.5	0.0
2388	3270	6.1	24.5	0.0	2495	3126	19.2	100.1	0.0
2392	3260	28.1	10.8	0.0	2497	4149	17.0	369.6	26.1
3243	3260	18.8	345.6	0.0					
IND	75								
2203	2212	14.6	19.1	0.0	3183	3186	6.1	18.9	0.0
2212	3232	11.3	35.7	0.0	3182	3183	9.0	31.3	0.0
2221	3232	9.1	95.5	0.0	2267	3172	13.3	167.9	0.0
2069	2221	7.6	261.7	0.0	3171	3172	16.2	48.0	0.0
2069	3186	8.1	68.3	0.0	3170	3171	7.9	26.7	0.0
IND	101								
2650	3197	11.8	21.7	0.0	2613	2530	6.6	35.0	0.0
3195	3197	7.3	99.0	0.0	2530	2662	20.0	20.3	0.0
3192	3195	9.8	158.3	0.0	2662	3066	5.1	253.6	30.3
2013	3192	1.2	199.5	0.0	2551	3066	13.5	38.7	0.0
2312	2511	25.3	85.4	0.0	2551	3067	8.1	66.3	0.0
2513	3106	7.8	17.5	0.0	3067	3068	11.5	35.1	0.0
IND	114								
2362	4373	25.0	61.9	0.0	3041	3047	10.4	209.1	0.0
2362	3003	3.1	90.4	0.0	3047	3051	6.7	122.4	0.0
3003	3006	6.8	56.4	.1	3051	3052	5.5	143.0	0.0
2091	3006	5.5	165.8	0.0	3052	3055	9.8	158.1	0.0
2091	2405	7.0	140.5	0.0	3055	3060	3.6	131.4	0.0
2256	2405	21.2	19.7	0.0	3060	3062	7.2	91.4	0.0
3021	3022	7.7	4.7	0.0	2568	3062	8.3	97.9	0.0
IND	126								
2543	3093	10.5	196.3	1.1	3102	3103	6.8	106.1	1.3
3093	3094	7.6	211.5	1.1	3103	3104	10.1	107.0	1.3
3094	3096	17.1	86.4	1.1	3104	3105	6.3	256.6	1.3
3096	3097	4.1	80.3	1.1	2600	3105	9.6	243.0	1.3
3097	3100	4.6	77.7	1.1	2600	3106	9.6	219.8	1.3
3100	3101	4.3	77.7	1.1	3106	4133	5.0	218.6	1.3
3101	3102	5.0	265.1	1.3					

TABLE A1 (CONTINUED)

IND 135									
2630	3245	26.0	22.5	0.0	2445	3333	8.6	37.3	0.0
3245	3246	6.5	13.8	0.0	3320	3333	22.7	22.7	0.0
3246	3247	4.2	95.1	0.0	2431	3320	23.8	32.7	0.0
3247	3248	10.0	60.2	0.0	2431	3325	10.5	46.7	0.0
3248	3255	10.7	86.1	0.0	2040	3325	9.1	30.6	0.0
3254	3255	7.1	60.5	0.0	2040	2426	4.7	139.3	0.0
3252	3253	29.0	5.5	0.0	2426	3314	25.6	37.7	0.0
2444	3252	9.1	86.6	0.0					
IND 218									
2251	3170	18.0	22.7	0.0	3110	3111	6.9	115.0	0.0
3170	3174	11.3	30.5	0.0	3110	3111	6.9	109.8	0.0
2480	3173	11.0	20.4	0.0	3109	3110	8.6	113.0	0.0
2275	2480	10.7	30.3	0.0	3108	3109	8.9	92.8	0.0
2274	3088	13.1	.7	0.0	3107	3108	7.6	62.8	0.0
3095	3098	7.5	185.7	0.0	2499	3107	7.5	78.7	0.0
3098	3099	7.6	205.8	0.0	2499	4167	14.0	42.3	0.0
3110	3099	.9	226.7	0.0					
IND 236									
3223	4350	17.0	0.0	0.0	3138	3140	18.1	19.1	0.0
2351	3223	18.8	4.3	0.0	2289	3137	6.2	11.5	0.0
2351	3227	6.7	4.1	0.0	3136	3137	4.1	166.7	0.0
3227	3228	17.6	6.3	0.0	3135	3136	5.7	30.6	0.0
2397	3228	5.2	48.7	0.0	3133	3135	4.6	95.5	0.0
2221	2397	22.6	57.1	0.0	3132	3133	16.8	.8	0.0
2265	3138	3.2	144.0	0.0					
IND 250									
2445	3334	4.3	133.2	0.0	3209	3219	17.7	0.0	0.0
3334	3337	8.0	133.7	0.0	2457	3204	7.8	25.7	0.0
2326	3337	.6	133.3	0.0	3204	3205	16.8	0.0	0.0
2027	2326	.5	180.0	0.0	3206	3206	16.6	0.0	0.0
2027	3219	16.0	0.0	0.0	3203	3206	15.3	0.0	0.0
IND OTHER HIGHWAYS									
2492	3032	18.6	7.3	0.0	2487	3186	1.6	56.6	0.0
3031	3032	16.8	7.3	0.0	2208	3236	15.1	0.0	0.0
2285	3031	10.7	48.3	0.0	3236	3237	15.7	0.0	0.0
2525	3077	13.1	160.3	0.0	3237	3238	23.2	0.0	0.0
2123	3076	9.9	3.0	0.0	2364	3238	7.6	0.0	0.0
2123	2508	3.6	38.3	0.0	2397	3240	13.2	1.3	0.0
2455	3217	15.7	5.4	0.0	3240	3241	18.6	0.0	0.0
3209	3210	6.9	7.6	0.0	3241	3242	11.0	33.1	0.0
2447	3209	25.8	7.6	0.0	2256	3169	16.5	123.7	0.0
2322	2447	26.8	13.7	0.0	2086	3169	17.1	170.5	0.0
2320	2321	11.3	1.1	0.0	2086	2252	6.2	327.5	0.0
3316	3315	13.3	3.0	0.0	2391	3259	18.0	31.1	0.0
3315	3316	13.0	0.0	0.0	3259	3260	18.7	31.1	0.0
2427	3316	16.0	0.0	0.0	3264	3260	19.3	41.8	0.0
2446	3337	13.2	0.0	0.0	2315	3264	9.2	94.6	0.0
2481	3019	16.3	115.1	0.0	2020	2315	7.3	367.7	0.0
3019	3022	7.1	47.7	0.0	2020	3190	23.3	325.9	0.0
3022	3023	13.0	37.8	0.0	2006	3188	7.7	230.2	0.0
3023	3024	10.8	59.2	0.0	2006	2309	26.2	246.5	0.0
3024	3026	7.7	13.5	0.0	2309	3188	30.3	333.1	0.0
3026	3028	13.5	15.8	0.0	2511	3188	19.5	215.7	0.0
3026	3020	5.7	3.0	0.0	2511	4101	13.0	40.6	0.0
2462	3020	15.8	35.3	0.0	3256	3256	35.0	33.6	0.0

TABLE A1 (CONTINUED)

2543	3088	13.2	45.1	0.0	3254	3257	7.6	160.1	0.0
3088	3090	13.9	45.7	0.0	3257	3260	21.5	128.3	0.0
2478	3176	26.5	4.1	0.0	3260	3267	12.7	95.1	0.0
3108	2471	11.5	143.7	0.0	2366	3363	13.1	119.7	0.0
3104	3123	3.3	64.7	0.0	2370	2372	12.9	0.0	0.0
3122	3123	6.0	8.7	0.0	2366	2290	10.6	20.8	0.0
3117	3121	11.2	74.3	0.0	2364	3274	16.7	30.7	0.0
3116	3117	9.2	67.6	0.0	3273	3274	8.6	107.8	0.0
2494	3116	13.2	150.3	0.0	2380	3273	20.2	67.0	0.0
2496	4158	16.0	38.0	0.0	3257	3259	13.0	0.0	0.0
2287	4007	26.3	0.0	0.0	3194	3198	16.3	0.0	0.0
2287	2614	13.6	0.0	0.0	3195	3196	13.9	74.7	0.0
2614	3034	7.1	0.0	0.0	2453	3196	14.3	3.3	0.0
3033	3034	7.5	87.3	0.0	2610	2611	1.5	48.7	0.0
3031	3033	6.5	87.3	0.0	2160	2610	1.1	420.1	0.0
2583	3031	7.9	121.2	0.0	2149	2160	7.0	4.3	0.0
2565	2583	10.3	80.1	0.0	2149	2586	7.9	611.2	33.3
2565	3030	9.2	116.4	0.0	2586	3036	13.0	162.7	0.0
3028	3030	5.3	127.1	0.0	3035	3036	4.8	187.0	0.0
2246	3177	16.3	159.2	0.0	2567	3011	16.0	63.4	0.0
3176	3177	6.5	260.5	0.0	3009	3011	16.1	32.1	0.0
3175	3176	7.0	247.8	0.0	3008	3009	16.8	7.7	0.0
3174	3175	6.8	230.0	0.0	2569	2588	20.2	0.0	0.0
3173	3174	5.0	233.6	0.0	2094	2570	6.8	0.0	0.0
3173	3185	5.7	219.0	0.0	2152	2570	11.3	0.0	0.0
2481	3185	6.5	169.0	0.0	2343	3292	17.2	5.5	0.0
3185	3186	1.5	50.0	0.0	2344	3273	17.2	71.8	0.0
		END OTHER HIGHWAYS							
3271	3272	16.5	67.5	0.0	2373	3305	9.1	11.3	0.0
3272	3273	18.3	35.6	0.0	3305	3306	4.4	93.5	67.6
3270	3271	10.3	73.1	0.0	3306	3307	9.4	66.1	0.0
2387	3270	4.7	72.2	0.0	3309	3310	6.1	0.0	0.0
2386	3240	18.6	91.5	0.0	2241	3159	16.1	16.1	0.0
3260	3261	13.8	80.4	0.0	3159	3160	9.4	9.2	0.0
2442	3261	21.3	98.7	0.0	2218	3226	16.5	33.6	0.0
2049	2333	16.7	391.2	33.4	2218	3233	16.1	28.2	0.0
2049	3291	1.6	217.5	0.0	2305	3131	21.2	12.0	0.0
3291	3294	7.2	227.6	0.0	2583	3032	12.8	0.0	0.0
3294	3296	7.0	238.8	0.0	3054	3058	6.9	84.6	0.0
3296	3302	20.8	179.7	0.0	3055	3056	5.4	78.0	0.0
2438	3302	26.3	158.3	0.0	3056	3057	7.7	38.0	0.0
2438	3263	18.6	191.5	0.0	2539	3057	6.1	77.3	0.0
3263	3266	8.9	147.5	0.0	2539	3096	16.9	46.5	0.0
2387	3266	19.3	110.5	0.0	3096	3098	7.3	77.1	0.0
2342	3282	20.1	15.8	0.0	2456	3210	6.2	29.5	0.0
2342	3268	16.9	45.7	0.0	3210	3211	8.1	31.7	0.0
3267	3268	10.1	25.6	0.0	2517	2555	15.5	106.4	0.0
3266	3267	0.0	20.3	0.0	3146	3147	18.4	3.4	0.0
2383	3264	15.6	17.5	0.0	2102	3146	13.9	.7	0.0
3261	3262	10.3	74.1	0.0	2153	2203	6.7	335.3	0.0
2442	3252	41.3	0.0	0.0	2296	3136	2.1	176.0	0.0
2322	3252	28.4	79.1	0.0	3133	3136	7.6	415.7	0.0
2440	3337	11.8	79.4	0.0	2132	3133	9.7	480.0	0.0
3329	3337	38.3	37.9	0.0	2137	2303	6.7	401.5	0.0
3328	3329	19.8	8.7	0.0	2276	3062	7.3	22.8	0.0
3327	3328	10.5	74.5	0.0	2370	3028	9.2	16.0	0.0

TABLE A1 (CONTINUED)

2331	3327	5.0	24.5	0.0	3024	3025	3.8	15.0	0.0
2034	2331	1.6	8.1	.7	2407	3010	3.3	41.7	0.0
2416	3300	14.6	17.9	0.0	2036	3327	12.8	0.0	0.0
2048	2416	15.8	274.4	24.5	2035	3317	22.9	0.0	0.0
2048	3292	1.3	68.7	0.0	3052	3056	15.4	0.0	0.0
3292	3297	16.7	30.7	0.0	3054	3059	5.0	0.0	0.0
3297	3301	12.6	31.1	0.0	2542	3049	4.9	0.0	0.0
3302	3304	17.5	66.1	0.0	2533	3104	14.4	197.6	0.0
2339	3304	18.1	45.9	0.0	3104	3107	16.4	0.0	0.0
2051	2415	15.5	0.9	0.0	2498	3107	13.0	17.9	0.0
2051	3285	7.9	0.0	0.0	3025	3026	7.0	0.0	0.0
3284	3285	8.3	20.7	0.0	2290	3025	12.3	0.0	0.0
3283	3284	9.8	45.3	0.0	2484	3014	20.2	17.4	0.0
3294	3303	21.6	10.9	0.0	2525	3078	14.6	147.8	0.0
2413	3286	17.2	34.6	0.0	2598	3079	14.7	4.7	0.0
3285	3286	10.9	0.0	0.0	3079	3080	12.5	19.3	0.0
2334	3285	12.9	0.0	0.0	3080	3081	7.8	84.2	0.0
2334	3291	6.6	7.1	0.0	3081	3082	10.3	27.3	0.0
3291	3292	12.1	2.9	0.0	3082	3083	7.8	91.9	0.0
3292	3293	15.9	8.0	0.0	3083	3084	11.5	22.9	0.0
2377	3293	10.0	7.5	0.0	3072	3084	18.0	14.3	0.0
2413	3287	22.8	52.5	0.0	3071	3072	11.5	18.8	0.0
IND. OTHER HIGHWAYS									
2310	3188	25.3	14.9	0.0	2379	3326	29.0	7.3	0.0
2512	3187	6.6	14.9	0.0	2414	3286	8.6	0.0	0.0
2615	3034	2.3	87.3	0.0	2052	3286	1.6	97.4	0.0
2607	2615	12.6	0.0	0.0	2052	3284	16.7	21.6	0.0
2233	3166	4.2	47.6	0.0	3119	3125	15.3	107.2	0.0
3147	3149	29.8	0.0	0.0	2335	3284	12.0	26.8	0.0
3203	3205	22.8	10.0	0.0	2336	3294	12.7	18.1	0.0
3205	3207	5.2	10.0	0.0	3215	3216	6.3	0.0	0.0
3207	3208	3.3	48.3	0.0	3216	3217	4.8	0.0	0.0
2469	3208	12.8	9.5	0.0	3056	3063	15.8	70.6	0.0
2588	3037	17.4	0.0	0.0	2554	3063	4.1	48.0	0.0
3036	3037	7.4	237.2	0.0	2515	2554	16.7	103.6	0.0
2292	3143	17.6	75.3	0.0	2515	3069	10.4	67.1	0.0
3242	3251	13.9	1.3	0.0	2504	3069	5.5	45.9	0.0
3242	3243	7.4	253.0	0.0	2302	3135	10.5	28.9	0.0
3243	3244	10.9	7.0	0.0	2486	3077	6.2	113.7	.5
2315	3245	9.2	42.9	0.0	3316	3317	2.7	0.0	0.0
2421	3308	22.9	7.4	0.0	2606	2618	6.9	0.0	0.0
2044	2421	.9	18.4	0.0	3142	3152	15.7	99.5	0.0
2244	3319	17.3	40.9	0.0	3152	3155	15.2	30.0	0.0
3320	3326	3.4	22.7	0.0	2478	3155	4.6	46.6	0.0
2436	3326	27.4	.8	0.0	2528	2601	2.5	40.6	0.0
2452	3196	6.3	21.4	0.0	2469	3124	5.0	41.7	0.0
2587	3037	5.1	232.7	0.0	3122	3124	2.7	329.5	0.0
2587	2613	4.6	232.7	0.0	3112	3123	6.8	12.8	0.0
2612	2613	1.8	0.0	0.0	3009	3112	12.9	0.0	0.0
2345	3251	17.7	14.7	0.0	3009	3100	7.1	0.0	0.0
3251	4337	9.0	52.4	0.0	2537	3100	17.5	0.0	0.0
3202	3233	25.9	0.0	0.0	2287	3033	23.1	0.0	0.0
3201	3252	14.0	0.0	0.0	3187	4191	13.0	22.8	0.0
2360	3274	27.0	21.8	0.0	2307	3187	13.4	22.5	0.0
2386	2389	16.9	105.7	0.0	2129	2307	6.4	25.5	0.0
3264	3268	8.6	56.6	0.0	2139	3300	18.6	165.4	19.4

TABLE A1 (CONTINUED)

3274	3276	4.4	157.3	0.0	2300	3129	15.4	113.9	0.0
3276	3278	18.8	0.0	0.0	2012	2311	18.0	53.5	0.0
2031	3329	29.1	81.0	0.0	2012	3193	.2	289.9	0.0
2031	2328	.6	101.7	0.0	3193	3194	14.2	17.6	0.0
2328	3214	15.5	101.7	0.0	2459	3194	5.6	17.6	0.0
2371	2417	18.6	75.7	76.5	2463	3333	13.3	4.1	0.0
2418	3293	17.2	13.7	0.0	2349	3231	11.8	19.7	0.0
3293	3299	15.0	9.1	0.0	3230	3231	3.6	48.3	0.0
2378	3312	2.5	.8	0.0	2306	3230	11.9	76.5	0.0
3312	3313	6.7	5.4	0.0	2396	3232	20.9	8.4	0.0
2419	3313	5.0	139.7	67.6	2711	3232	16.1	17.2	0.0
2045	2419	3.0	190.5	67.6	3139	3140	3.9	606.6	0.0
2045	3318	12.1	187.9	0.0	2098	3139	6.3	365.1	0.0
2379	3318	12.6	155.3	0.0	2098	2290	10.8	217.3	0.0
3233	6330	16.0	65.7	0.0	2203	3305	17.9	73.3	0.0
3233	3236	6.8	96.5	0.0	2338	3306	19.2	67.8	0.0
2368	3236	7.6	27.0	0.0	2439	3306	5.6	88.9	0.0
		IND	OTHER HIGHWAYS						
3238	3239	6.9	0.0	0.0	2529	2582	26.9	44.5	0.0
2060	3239	1.9	0.0	0.0	2529	2619	3.8	0.0	0.0
2060	2205	6.9	0.0	0.0	2199	2262	11.2	0.0	0.0
2007	3180	15.8	69.2	0.0	2430	3328	13.6	10.6	0.0
2625	3180	13.9	37.6	0.0	2426	3315	16.3	0.0	0.0
2372	3306	16.3	72.8	67.6	2426	3326	17.6	36.1	0.0
3306	3313	11.6	143.5	67.6	3330	3331	18.3	14.3	0.0
2377	3313	16.8	0.0	0.0	3165	3168	7.5	15.5	0.0
2347	3279	8.0	7.1	0.0	2224	3168	11.4	10.6	0.0
2347	3276	12.3	136.9	0.0	2224	3226	7.3	13.5	0.0
3275	3278	12.1	56.6	0.0	3226	3227	8.3	7.1	0.0
2390	3275	30.2	15.0	0.0	2306	3230	6.1	0.0	0.0
2158	2617	6.1	0.0	0.0	2376	3312	4.1	4.6	0.0
3248	3249	13.9	73.6	0.0	2458	3197	16.2	44.2	0.0
2316	3247	11.6	22.2	0.0	2452	3197	20.9	30.3	0.0
2021	2317	7.1	0.0	0.0	2359	3160	8.8	15.5	0.0
2029	3335	8.8	0.0	0.0	2359	3162	10.4	61.3	0.0
2029	2336	1.0	618.4	0.0	2235	3162	4.4	88.7	0.0
2325	3218	1.0	476.9	0.0	3300	3302	16.9	32.8	0.0
3211	3218	14.8	342.2	0.0	2327	3221	6.1	1.7	0.0
3298	3300	14.3	25.5	0.0	3216	3221	4.7	0.0	0.0
2438	3300	24.7	101.9	0.0	3212	3216	9.9	0.0	0.0
2446	3252	22.2	0.0	0.0	3263	3264	16.6	69.4	0.0
2416	3289	10.7	54.4	0.0	2383	3263	19.7	54.8	0.0
3288	3289	6.2	41.7	0.0	3213	3215	10.4	1.7	0.0
2451	3200	24.1	6.0	0.0	2329	3214	10.6	217.9	0.0
2066	2076	11.6	185.9	6.2	2507	3070	14.0	82.6	0.0
2066	2210	2.9	302.6	0.0	3070	4083	12.0	85.8	0.0
2210	2219	9.8	90.0	0.0	2266	3138	3.2	46.0	0.0
2201	2210	7.7	81.4	0.0	2620	3138	12.6	0.0	0.0
2201	3242	13.2	45.0	0.0	2437	2447	36.3	81.5	0.0
2531	3105	8.1	10.3	0.0	2475	3090	9.3	145.2	0.0
3105	3107	9.6	33.9	0.0	2078	3186	12.0	59.6	0.0
2533	3066	8.6	0.0	0.0	2420	3307	20.6	37.6	0.0
2533	3103	8.0	59.1	0.0	2361	3265	8.2	76.6	0.0
3103	3108	8.2	51.0	0.0	2430	3265	13.9	76.8	0.0
3109	3116	10.6	76.6	0.0	2381	2435	16.3	56.6	0.0
3116	3117	8.0	92.6	0.0	3001	3003	7.6	0.0	0.0

TABLE A1 (CONTINUED)

3117	3120	3.4	70.1	0.0	2671	3288	21.4	23.7	0.0
2524	2579	4.2	22.0	0.0	3288	3295	10.3	24.6	0.0
3084	4025	17.0	33.2	0.0	2510	3072	15.4	31.2	0.0
2592	3084	9.1	43.4	0.0	2526	2599	3.0	200.9	0.0
2593	3076	11.1	4.4	0.0	2137	2387	6.4	445.7	75.5
2573	3076	8.8	4.4	0.0	2096	2588	11.6	0.0	0.0
2505	2573	9.0	27.3	0.0	2307	4158	42.0	56.2	0.0
3042	3043	6.7	80.5	0.0	2312	4216	28.0	30.1	0.0
2560	3043	4.6	165.1	0.0	3187	4169	14.0	14.9	0.0
2560	2582	18.8	53.6	0.0	3316	4273	3.0	37.7	0.0
IND	OTHER HIGHWAYS								
2001	2179	17.9	0.0	0.0	2173	2630	3.6	10.3	0.0
2128	2627	14.0	0.0	0.0	2174	2626	1.9	871.4	0.0
2165	2169	14.6	81.9	0.0	2174	2630	4.6	17.2	0.0
2166	2627	14.2	0.0	0.0	2176	2628	11.0	48.7	0.0
2167	2629	.9	0.0	0.0	2177	2628	10.9	168.1	0.0
2168	2627	16.8	0.0	.4	2179	2626	1.5	709.3	0.0
2169	2627	4.6	0.0	0.0	2187	2188	15.8	0.0	0.0
2169	2628	6.1	0.0	0.0	2187	2628	2.8	0.0	0.0
2170	2179	14.3	0.0	0.0	2198	2628	15.0	0.0	0.0
2172	2626	2.4	353.3	0.0	2626	2628	1.3	213.3	0.0
2172	2627	6.0	0.0	0.0	2627	2629	15.8	0.0	0.0

Table A2. Centroid Link Table.

CENTROID NAME	HWY NODE	CENT NODE	DIST ANCE	PHASE II ITDF	CENTROID NAME	HWY NODE	CENT NODE	DIST ANCE	PHASE II ITDF
NEW BUFFALO,MI	2618	14	10.0	18.3	CROWN POINT	2412	663	.5	474.0
NEW BUFFALO,MI	4001	14	4.0	0.0	ST. JOHN	2367	664	3.3	59.4
ANSONIA,OH	3129	164	15.0	47.3	ST. JOHN	2368	664	5.7	77.1
ANSONIA,OH	4155	164	5.0	0.0	LA PORTE	2492	665	.5	770.7
UNION CITY,OH	3129	166	1.0	147.7	MICHIGAN CITY	2608	666	1.0	1006.4
HARRISON,OH	2015	185	5.0	85.9	KINGSFORD HTS.	2490	667	2.5	58.7
HARRISON,OH	2016	185	5.0	0.0	KINGSFORD HTS.	2491	667	4.3	82.4
CLEVES,OH	1749	186	7.0	0.0	PLYMOUTH	2562	668	.5	371.5
CLEVES,OH	2454	186	8.0	89.9	CULVER	3026	669	.5	135.9
NEW PARIS,OH	2141	244	4.3	0.0	ARGOS	2280	670	.7	148.0
NEW PARIS,OH	2307	244	8.0	84.1	MOROCCO	2362	671	1.0	114.5
LOGANSPORT	2481	656	.5	564.7	GOODLAND	2545	672	1.0	114.8
ROCHESTER	2278	657	.5	245.1	KENTLAND	2240	673	2.3	116.9
REMINGTON	2403	658	.7	122.5	KENTLAND	2241	673	4.6	29.8
RENSSELAER	2405	659	.5	338.0	HEBRON	2411	674	.7	120.0
GARY	2154	660	10.0	2193.4	VALPARAISO	3036	675	.5	573.8
GARY	2156	660	10.0	956.7	KOUTS	3011	676	.7	94.9
LOWELL	2366	661	7.8	74.5	CHESTERTON	2149	677	6.1	72.4
LOWELL	3007	661	10.8	75.4	CHESTERTON	2160	677	1.1	453.2
CEDAR LAKE	2366	662	17.3	112.1	WINAMAC	2484	678	.7	142.5
CEDAR LAKE	2367	662	8.6	230.2	FRANCESVILLE	2256	679	5.3	41.5
FRANCESVILLE	2257	679	4.1	49.6	SYRACUSE	2579	704	4.0	110.5
SOUTH BEND	2287	680	1.0	1523.6	SYRACUSE	3073	704	8.0	65.4
NORTH LIBERTY	3031	681	.7	133.8	MILFORD	933	705	8.7	11.0
WALKERTON	2583	682	.7	188.7	MILFORD	2558	705	19.1	42.1
NEW CARLISLE	2603	683	11.6	60.4	MILFORD	2580	705	6.7	79.0
NEW CARLISLE	2604	683	6.5	106.3	PIERCETON	2557	706	2.7	122.6
LYDICK	2606	684	12.8	49.5	PIERCETON	3053	706	15.0	16.3
LYDICK	2616	684	3.8	35.3	WARSAW	2558	707	.5	421.8
KNOX	2487	685	.7	192.4	WINONA LAKE	2557	708	7.3	97.2
NORTH JUDSON	3016	686	.7	130.4	WINONA LAKE	2558	708	8.4	103.2
MONON	2255	687	.7	111.8	LAGRANGE	2594	709	.7	157.4
MONTICELLO	2253	688	1.8	38.3	BOURBON	2560	710	.7	163.4
MONTICELLO	2254	688	7.5	121.7	BREMEN	2582	711	.7	193.9
DEMOTTE	2409	689	.5	98.4	PERU	2543	712	.5	546.7
BURNETTSVILLE	2487	690	15.4	46.8	ALBION	3085	713	.7	130.5
BURNETTSVILLE	2544	690	12.8	63.4	KENDALLVILLE	2574	714	.5	373.5
FORT WAYNE	2503	691	1.0	1219.5	LIGONIER	2521	715	.7	217.6
NEW HAVEN	2553	692	.7	251.1	OSCEOLA	2528	716	1.4	60.7
MONROEVILLE	2530	693	14.7	35.6	OSCEOLA	2529	716	16.0	44.8
MONROEVILLE	2552	693	6.0	50.9	ANGOLA	2510	717	.5	373.2

TABLE A2 (CONTINUED)

WATERLOO	2507	694	.7	184.7	MANCHESTER	3057	718	.4	236.1
AUBURN	2506	695	.5	678.5	WABASH	2623	719	.5	484.5
GARRETT	2504	696	6.5	95.5	OSSIAN	2532	720	5.6	80.0
GARRETT	2505	696	3.7	100.3	OSSIAN	3045	720	15.8	30.8
BUTLER	2572	697	.2	183.0	SOUTH WHITLEY	3054	721	.2	142.8
ELKHART	2599	698	1.0	807.4	COLUMBIA CITY	3063	722	.5	279.0
DUNLAP	2525	699	13.0	72.4	CHURUBUSCO	2438	723	.2	127.3
DUNLAP	2526	699	9.8	91.4	TRI LAKES	2516	724	5.0	45.8
GOSHEN	2535	700	.5	531.5	TRI LAKES	2585	724	9.5	68.7
NAPPANEE	2581	701	.5	230.9	GRABILL	2649	725	26.8	30.1
WAKARUSA	2527	702	17.7	20.7	GRABILL	3067	725	10.7	51.0
WAKARUSA	3078	702	2.9	80.2	ASHLEY	2123	726	1.8	150.5
HUNTINGTON	2597	703	.5	673.2	WOLCOTTVILLE	2575	727	10.1	67.4
WOLCOTTVILLE	2594	727	14.2	58.1	GREENFIELD	2301	747	.5	605.8
LAKE JAMES	2126	728	5.0	99.2	FORTVILLE	2290	748	.2	314.0
LAKE JAMES	3084	728	14.5	4.3	MIDDLETOWN	2102	749	9.0	184.7
DECATUR	2501	729	.5	375.2	NEW CASTLE	3130	750	16.5	207.0
MONTPELIER	3114	730	.2	152.6	NEW CASTLE	3131	750	2.7	518.7
HARTFORD CITY	3121	731	.5	456.1	KNIGHTSTOWN	2303	751	.2	302.3
MUNCIE	2465	732	1.0	1091.8	GREENTOWN	2476	752	.2	151.1
ALBANY	3125	733	.2	222.9	ANDREWS	2539	753	1.9	104.8
YORKTOWN	735	734	10.0	33.3	ANDREWS	3096	753	15.0	29.6
YORKTOWN	2104	734	12.4	85.2	WARREN	3111	754	.2	140.8
YORKTOWN	2465	734	13.6	50.5	DUNKIRK	3119	755	6.6	96.5
DALEVILLE	2104	735	7.5	245.5	DUNKIRK	3125	755	9.1	138.7
DALEVILLE	2465	735	23.5	17.2	REDKEY	3126	756	.2	167.0
EATON	2467	736	8.3	107.7	PORTLAND	2495	757	.5	353.5
EATON	3121	736	14.7	48.3	ANDERSON	3145	758	1.0	907.6
MARION	3092	737	1.0	907.5	ELWOOD	3151	759	.5	566.2
FAIRMOUNT	2107	738	8.8	146.9	PENDLETON	2100	760	4.0	184.6
FAIRMOUNT	3158	738	3.4	149.0	PENDLETON	2292	760	3.0	89.7
UPLAND	3122	739	3.6	139.9	FRANKTON	3147	761	11.1	41.7
UPLAND	3123	739	3.6	68.8	FRANKTON	3149	761	9.1	93.5
GAS CITY	2471	740	.6	509.6	ALEXANDRIA	3148	762	.6	500.1
CARMEL	3138	741	.2	207.1	LAPEL	3143	763	1.8	64.4
ARCADIA	743	742	6.3	35.5	LAPEL	3144	763	5.6	143.4
ARCADIA	960	742	5.6	24.3	CHESTERFIELD	2106	764	2.6	317.1
ARCADIA	3140	742	15.7	55.7	CHESTERFIELD	3146	764	9.6	16.8
ARCADIA	3153	742	16.7	45.1	SUMMITVILLE	3148	765	7.9	101.6
CICERO	3140	743	9.6	137.5	SUMMITVILLE	3158	765	9.7	66.9
CICERO	3158	743	22.8	22.0	CONVERSE	3090	766	1.2	139.2
NOBLESVILLE	3140	744	.5	586.9	BUNKER HILL	2276	767	4.3	95.3
WESTFIELD	2247	745	.2	203.1	BUNKER HILL	3088	767	9.0	16.5
SHIRLEY	963	746	4.9	32.6	FARMLAND	3129	768	.8	136.5
SHIRLEY	3132	746	13.6	18.4	PARKER CITY	954	769	4.0	50.9
SHIRLEY	3133	746	4.2	143.6	PARKER CITY	2465	769	15.3	65.7
PARKER CITY	3128	769	8.0	63.1	COVINGTON	2074	795	2.5	177.4
LYNN	2289	770	.2	138.4	COVINGTON	2226	795	6.3	26.3
UNION CITY	3139	771	.5	260.3	VEEDERSBURG	2225	796	.2	171.0
WINCHESTER	2433	772	2.8	290.4	SHERIDAN	2266	797	9.0	75.1
WINCHESTER	3128	772	15.3	35.2	SHERIDAN	3181	797	1.6	136.7

TABLE A2 (CONTINUED)

TIPTON	3153	773	.5	396.2	BROWNSBURG	2219	798	.5	381.7
WINDFALL	3152	774	8.4	73.5	KOKOMO	2478	799	1.0	826.6
WINDFALL	3155	774	7.0	64.5	RUSSIAVILLE	2271	800	10.1	80.7
RICHMOND	2307	775	1.0	1121.0	RUSSIAVILLE	3177	800	9.0	41.1
CENTERVILLE	2307	776	9.9	149.1	CRAWFORDSVILLE	2222	801	.5	519.1
CENTERVILLE	2672	776	11.1	94.2	LAFAYETTE	2400	802	1.0	823.8
CAMBRIDGE CITY	2306	777	1.0	311.2	WILLIAMSPORT	2356	803	1.3	123.0
HAGERSTOWN	3130	778	.5	181.3	WILLIAMSPORT	3161	803	9.2	34.5
BLUFFTON	3104	779	.5	340.2	BROOKSTON	3169	804	.2	133.3
SPICELAND	2133	780	2.7	116.5	FOWLER	2238	805	.2	170.3
SPICELAND	2304	780	5.2	59.6	OXFORD	3162	806	.2	109.1
BRONSON	2297	781	1.0	146.7	CHARLESTOWN	3214	807	.5	319.4
HOMEPLACE	2144	782	.5	201.7	SELLERSBURG	2330	808	.2	306.4
BERNE	2499	783	.2	178.0	AURORA	2452	809	.5	264.0
GENEVA	2498	784	.2	107.7	LAWRENCEBURG	2453	810	.5	522.9
LEBANON	3180	785	.5	547.5	GREENSBURG	2460	811	.5	391.5
ZIONSVILLE	2199	786	8.1	83.0	CONNERSVILLE	3188	812	.5	518.4
ZIONSVILLE	2242	786	3.3	153.6	NEW ALBANY	2429	813	1.0	1574.1
THORNTOWN	3182	787	.2	166.0	BROOKVILLE	2312	814	.2	163.3
DELPHI	2251	788	.2	185.9	SEYMOUR	2446	815	.5	460.1
FLORA	3171	789	.2	151.5	CROTHERSVILLE	2028	816	3.0	106.9
GALVESTON	2479	790	.2	139.7	CROTHERSVILLE	2324	816	6.1	72.1
WALTON	2480	791	.2	124.0	HANOVER	3211	817	4.4	41.4
FRANKFORT	2247	792	.5	551.7	HANOVER	3212	817	5.8	58.9
MULBERRY	1005	793	9.9	8.2	MADISON	2455	818	.5	360.0
MULBERRY	2083	793	12.3	66.6	NORTH VERNON	2447	819	.5	192.3
MULBERRY	2248	793	8.5	36.5	EDINBURG	2021	820	4.0	155.2
ATTICA	2354	794	.5	261.1	EDINBURG	2317	820	3.3	118.0
FRANKLIN	2315	821	.5	616.7	BICKNELL	3264	847	1.0	179.8
GREENWOOD	2018	822	4.0	507.4	BEDFORD	2442	848	.5	366.6
GREENWOOD	2314	822	3.5	171.2	OOLITIC	1070	849	13.7	3.2
NEW WHITELAND	2019	823	4.4	294.7	OOLITIC	2442	849	10.2	54.5
NEW WHITELAND	2314	823	3.2	120.4	OOLITIC	3257	849	32.5	18.5
NEW WHITELAND	2315	823	8.4	104.4	OOLITIC	3261	849	11.3	15.8
RISING SUN	3200	824	.2	107.0	CLERMONT	2198	850	5.1	147.9
BATESVILLE	3193	825	.2	283.2	CLERMONT	2219	850	9.8	26.8
OSGOOD	2458	826	.2	103.9	SHOALS	2436	851	.2	60.4
MILAN	3197	827	.5	124.8	LOOGOOTEE	2381	852	.2	128.4
VERSAILLES	2449	828	.2	89.0	BLOOMINGTON	3257	853	1.0	515.2
CARTHAGE	2303	829	12.0	89.9	ELLETTSVILLE	2391	854	14.1	48.6
CARTHAGE	2309	829	20.5	26.7	ELLETTSVILLE	3258	854	14.0	33.0
RUSHVILLE	2309	830	.5	410.5	MOORESVILLE	3242	855	.5	302.4
AUSTIN	2325	831	.2	321.9	MARTINSVILLE	3249	856	.5	356.1
SCOTTSBURG	2326	832	.5	265.6	SPENCER	2390	857	.2	130.9
SHELBYVILLE	3190	833	.5	589.8	ROCKVILLE	2215	858	.2	263.7
VEVAY	3203	834	.2	62.0	MONTEZUMA	2215	859	11.2	47.7
LIBERTY	2511	835	.2	152.6	MONTEZUMA	2216	859	2.3	77.5
HOWECROFT	2017	836	1.0	329.0	GREENCASTLE	2395	860	.5	374.3
COLUMBUS	2319	837	3.5	152.0	DUGGER	3272	861	.2	81.4
COLUMBUS	2321	837	3.5	449.0	FARMERSBURG	2346	862	5.9	56.2
HOPE	3190	838	24.5	53.1	FARMERSBURG	2347	862	3.2	67.2
HOPE	3199	838	7.5	65.1	SHELBURN	2346	863	.2	149.4

TABLE A2 (CONTINUED)

WASHINGTON	2438	839	.5	367.9	SULLIVAN	2344	864	5.8	70.9
WORTHINGTON	2389	840	.7	97.2	SULLIVAN	2345	864	1.0	126.0
BLOOMFIELD	2386	841	.7	111.8	HYMERA	2346	865	8.8	52.3
LINTON	3271	842	.5	248.6	HYMERA	3274	865	6.1	60.0
JASONVILLE	3273	843	2.1	84.8	CLINTON	2348	866	2.0	243.1
JASONVILLE	3274	843	6.7	69.6	CLINTON	3234	866	5.8	111.6
DANVILLE	2211	844	.2	237.7	TERRE HAUTE	2209	867	1.0	938.9
PLAINFIELD	2201	845	.5	466.6	SEELYVILLE	2207	868	2.5	83.3
BROWNSTON	2445	846	.7	166.1	SEELYVILLE	2208	868	11.7	61.4
COATESVILLE	2203	869	6.3	81.0	WINSLOW	3301	888	6.6	34.2
COATESVILLE	2212	869	8.3	39.2	PETERSBURG	3302	889	.2	145.2
BEN DAVIS	2176	870	3.5	257.1	MOUNT VERNON	3287	890	.5	179.4
BEN DAVIS	2201	870	9.3	56.5	NEW HARMONY	2413	891	.2	64.3
ST. BERNICE	2218	871	8.7	53.1	ROCKPORT	2371	892	5.1	72.9
ST. BERNICE	3233	871	5.6	56.0	ROCKPORT	2372	892	2.1	50.5
BRAZIL	2206	872	.5	480.9	EVANSVILLE	2332	893	1.0	841.1
ODON	2383	873	5.7	40.0	BOONEVILLE	2416	894	.5	189.2
ODON	3263	873	14.2	23.5	CHANDLER	2332	895	24.4	19.0
ODON	3266	873	10.1	22.8	CHANDLER	2416	895	9.8	84.7
HUNTINGBURG	2378	874	.5	168.6	NEWBURGH	3288	896	.2	74.4
OAKLAND CITY	3296	875	2.0	130.7	SALEM	3329	897	.5	162.0
OAKLAND CITY	3302	875	19.0	38.8	JASPER	2379	898	.5	254.5
HAUBSTADT	2334	876	3.1	102.1	FERDINAND	2045	899	3.5	71.6
HAUBSTADT	3285	876	10.0	8.2	FERDINAND	3318	899	8.8	32.0
OWENSVILLE	3284	877	.2	99.6	INDINAPOLIS	2626	900	2.0	2237.2
PRINCETON	3295	878	.7	348.1	KEWANNA	3022	901	9.1	19.6
FT. BRANCH	2335	879	1.5	149.9	KEWANNA	3023	901	4.1	33.1
FT. BRANCH	3284	879	17.1	12.3	WHEATFIELD	3008	902	1.3	45.6
CORYDON	2426	880	.7	132.1	WHEATFIELD	3011	902	13.0	14.7
VINCENNES	2339	881	.5	434.7	SCHNEIDER	2364	903	4.7	28.6
MITCHELL	3332	882	1.0	144.9	SCHNEIDER	2365	903	4.7	17.2
FRENCH LICK	1100	883	28.1	1.5	LA CROSSE	2761	904	.7	57.3
FRENCH LICK	2380	883	31.5	4.1	WESTVILLE	2264	905	2.5	33.3
FRENCH LICK	2434	883	4.3	68.9	WESTVILLE	2461	905	2.5	57.3
FRENCH LICK	3326	883	73.3	19.6	LA PAZ	2284	906	.9	56.8
ORLEANS	3331	884	.3	100.0	LA PAZ	2285	906	6.9	74.9
PAOLI	2433	885	.7	111.1	BROOK	3001	907	2.5	31.0
CANNELTON	3311	886	.7	97.8	BROOK	3002	907	5.5	36.7
TELL CITY	3307	887	7.3	93.8	BEVERLY SHORES	2609	908	4.5	49.3
TELL CITY	3308	887	9.2	82.9	BEVERLY SHORES	2611	908	5.2	58.7
TELL CITY	3311	887	9.6	76.8	MEDARYVILLE	2258	909	3.2	33.0
WINSLOW	3297	888	6.7	44.5	MEDARYVILLE	2259	909	10.9	26.9
LAKEVILLE	2285	910	.5	86.4	ETNA GREEN	2559	930	.2	80.7
HAMLET	2489	911	3.5	30.3	MENTONE	3045	931	.2	75.4
HAMLET	2565	911	6.0	33.0	SILVER LAKE	3046	932	.2	64.5
REYNOLDS	2254	912	.2	70.2	LEESBURG	2558	933	10.4	34.9
FULTON	3021	913	.2	41.4	LEESBURG	2580	933	14.2	17.5
WOLCOTT	2089	914	7.1	33.2	NORTH WEBSTER	2557	934	12.8	27.2
WOLCOTT	2402	914	7.4	44.4	NORTH WEBSTER	3073	934	5.7	29.3
SHELBY	3006	915	5.5	28.4	TOPEKA	2521	935	11.7	34.9
SHELBY	3007	915	10.0	19.3	TOPEKA	2606	935	13.6	20.5

TABLE 82 (CONTINUED)

HANNA	2262	916	8.0	27.5	DENVER	2277	936	5.0	32.1
HANNA	2566	916	7.9	33.6	DENVER	3038	936	4.1	33.8
ROLL. PRAIRIE	2604	917	4.0	40.5	AVILLA	3087	937	.2	107.9
ROLL. PRAIRIE	2605	917	10.5	33.6	CROMWELL	2519	938	4.1	48.3
WANATAH	2267	918	.5	90.2	CROMWELL	3075	938	3.2	71.6
BURLINGTON BCH.	2586	919	3.5	70.2	FREMONT	3072	939	.2	63.5
BURLINGTON BCH.	3036	919	10.1	20.5	ORLAND	3084	940	.2	45.3
STAR CITY	2483	920	12.4	21.9	LARGO	2539	941	10.0	38.3
STAR CITY	2484	920	11.2	23.1	LARGO	2540	941	5.0	45.6
ROYAL CENTER	2483	921	.2	72.9	ROANN	3039	942	7.3	23.6
ST. JOE	946	922	13.6	2.8	ROANN	3048	942	3.0	32.3
ST. JOE	2119	922	22.5	12.3	LARWILL	2556	943	.2	122.7
ST. JOE	3068	922	7.7	34.9	HAMILTON	3070	944	.2	50.5
MILLERSBURG	2522	923	6.7	33.7	HOAGLAND	2501	945	20.2	14.5
MILLERSBURG	3077	923	8.7	22.9	HOAGLAND	2502	945	21.5	20.1
MIDDLEBURY	2596	924	1.6	40.6	LEO	2119	946	9.1	43.6
MIDDLEBURY	3080	924	7.6	41.6	LEO	3068	946	21.1	10.6
BRISTOL	3079	925	.3	81.3	NEW PARIS	2526	947	11.7	40.2
AKRON	3041	926	.2	86.6	NEW PARIS	2580	947	5.8	56.9
ROANOKE	2547	927	8.0	50.6	HOWE	3082	948	.5	77.1
ROANOKE	2548	927	3.1	46.5	MEXICO	2276	949	6.3	45.4
MARKLE	2534	928	.2	91.9	MEXICO	2277	949	4.5	26.5
CLAYPOOL	2558	929	14.7	23.8	PLEASANT LAKE	2500	950	.2	100.6
CLAYPOOL	3046	929	8.4	28.0	LAKETON	3047	951	5.5	31.7
LAKETON	3051	951	5.5	20.2	SHARPSVILLE	2270	970	8.9	39.7
WOODBURN	2551	952	4.1	25.3	SHARPSVILLE	2271	970	3.3	52.4
WOODBURN	3066	952	6.6	31.8	LA FONTAINE	3094	971	7.3	24.6
MONROE	2500	953	1.9	45.3	LA FONTAINE	3095	971	1.5	56.9
MONROE	3106	953	7.9	16.4	GREENSFORK	2462	972	7.4	47.1
SELMA	2465	954	13.3	38.2	GREENSFORK	3130	972	11.8	22.7
SELMA	3128	954	11.6	26.4	FOUNTAIN CITY	2138	973	9.3	65.3
GASTON	2468	955	7.4	56.8	FOUNTAIN CITY	2299	973	10.7	31.3
GASTON	2469	955	11.8	36.4	SARATOGA	2696	974	6.9	39.2
SWEETSER	3091	956	5.2	48.7	SARATOGA	3179	974	12.4	26.6
SWEETSER	3092	956	12.8	46.7	CHARLOTTESVILLE	2302	975	5.1	43.9
MATTHEWS	2469	957	.5	99.1	CHARLOTTESVILLE	2303	975	5.5	57.0
SWAYZEE	2474	958	3.7	70.4	OGDEN	2303	976	6.5	77.5
SWAYZEE	3091	958	7.5	29.2	OGDEN	2304	976	2.0	78.8
VAN BUREN	3099	959	6.0	43.1	OAKLANDON	2128	977	7.4	57.0
VAN BUREN	3112	959	7.1	58.9	OAKLANDON	2289	977	5.4	36.4
ATLANTA	3140	960	21.2	20.4	OTTERBEIN	2235	978	6.3	30.2
ATLANTA	3153	960	11.2	38.0	OTTERBEIN	2236	978	6.2	36.9
MOORELAND	2296	961	7.0	36.1	ROSWELL	2358	979	.2	77.4
MOORELAND	2297	961	5.2	46.6	EARL PARK	2239	980	3.1	36.7
LEWISVILLE	2305	962	.2	126.8	EARL PARK	2240	980	9.6	26.5
KENNARD	3132	963	8.0	15.0	ADVANCE	2069	981	6.0	44.1
KENNARD	3133	963	9.0	44.2	ADVANCE	3184	981	2.3	30.2
MOUNT SUMMIT	2295	964	.2	126.2	JAMESTOWN	2221	982	.2	116.3
PENNVILLE	3116	965	.2	84.1	WHITESTOWN	2242	983	10.8	53.5
MARKLEVILLE	3132	966	13.9	3.1	WHITESTOWN	2243	983	8.4	24.5
MARKLEVILLE	3134	966	2.2	68.6	CAMDEN	3170	984	.2	63.2
CUMBERLAND	2170	967	4.5	114.7	KIRKLIN	2245	985	.2	80.8

TABLE A2 (CONTINUED)

CUMBERLAND	2301	967	17.2	34.3	MICHIGANTOWN	2246	986	5.6	36.8
AMBOY	3088	968	8.5	17.1	MICHIGANTOWN	3177	986	9.1	24.8
AMBOY	3089	968	7.6	40.0	COLFAX	2227	987	14.2	29.6
RIDGEVILLE	2494	969	5.2	50.9	COLFAX	2228	987	6.3	47.3
RIDGEVILLE	3127	969	9.3	45.4	ROSSVILLE	2249	988	.7	79.1
HILLSBORO	2226	989	.7	66.0	DILLSBORO	2451	1008	.7	59.7
LIZTON	2220	990	.7	79.0	MOORES HILL	2452	1009	17.9	19.5
PITTSBORO	2067	991	1.7	100.0	MOORES HILL	3197	1009	4.0	51.7
PITTSBORO	2219	991	7.4	38.3	ST. PAUL	2008	1010	3.3	87.9
WINGATE	3167	992	.7	54.8	WESTPORT	2447	1011	24.1	12.9
DARLINGTON	2222	993	17.9	71.0	WESTPORT	3198	1011	13.5	34.6
DARLINGTON	3182	993	13.8	40.5	LAUREL	2310	1012	7.6	39.9
LINDEN	1003	994	6.1	13.7	LAUREL	3188	1012	18.1	20.1
LINDEN	2071	994	12.0	36.6	OLDENBURG	2012	1013	4.3	111.0
LINDEN	2398	994	7.9	21.2	OLDENBURG	2311	1013	13.9	12.5
WAYNETOWN	2223	995	.7	93.7	NEW PALESTINE	2171	1014	15.4	46.7
CLARKS HILL	2228	996	.5	86.1	NEW PALESTINE	2308	1014	9.6	40.3
BATTLE GROUND	2085	997	6.0	58.2	SUNMAN	3192	1015	4.3	41.6
BATTLE GROUND	2251	997	16.1	14.9	SUNMAN	3195	1015	5.7	15.4
BATTLE GROUND	3169	997	13.5	8.9	MORRISTOWN	2308	1016	5.8	65.9
KEMPTON	2246	998	14.9	14.3	MORRISTOWN	2309	1016	22.2	8.3
KEMPTON	2270	998	8.8	42.4	W. COLL. CORNER	2511	1017	11.5	35.9
W. LEBANON	2226	999	14.3	20.0	W. COLL. CORNER	4187	1017	10.7	26.3
W. LEBANON	3161	999	1.9	36.1	GLENWOOD	2309	1018	12.6	27.7
CHALMERS	2254	1000	9.1	21.5	GLENWOOD	3188	1018	18.1	13.5
CHALMERS	3165	1000	7.6	45.0	TAYLORSVILLE	2022	1019	2.2	80.9
AMBIA	3160	1001	6.0	24.8	NEW WASHINGTON	3213	1020	4.1	24.7
NEWTOWN-MELLOTT	2224	1002	9.4	21.9	NEW WASHINGTON	3214	1020	16.3	21.5
NEWTOWN-MELLOTT	3168	1002	2.7	39.5	UTICA	2185	1021	25.9	17.3
NEW RICHMOND	2071	1003	18.0	20.6	UTICA	3216	1021	11.3	35.9
NEW RICHMOND	2398	1003	13.9	12.5	ACTON	2003	1022	2.3	124.3
BURLINGTON	3176	1004	.7	66.6	WANAMAKER	2002	1023	1.5	131.5
DAYTON	2083	1005	2.6	66.4	HOLTON	2447	1024	22.5	13.0
DAYTON	2248	1005	18.2	3.6	HOLTON	2448	1024	8.0	24.7
HARTSVILLE	3198	1006	12.2	13.8	MILROY	3189	1025	.5	86.0
HARTSVILLE	3199	1006	5.4	28.5	FAIRLAND	2004	1026	2.6	100.7
ELIZABETHTOWN	2320	1007	5.7	34.8	WALDRON	2008	1027	4.0	85.4
ELIZABETHTOWN	2447	1007	22.1	4.3	NASHVILLE	3254	1028	.2	39.0
CLAY CITY	3275	1029	.2	62.7	PARAGON	3250	1050	9.5	31.3
STAUNTON	2206	1030	5.7	65.4	GOSPORT	2392	1051	7.3	23.2
STAUNTON	2207	1030	4.6	31.6	GOSPORT	3250	1051	23.8	17.9
CARBON	2206	1031	11.5	28.6	ROSEDALE	2215	1052	14.0	19.9
CARBON	2214	1031	15.9	12.0	ROSEDALE	2348	1052	5.0	44.4
MONTGOMERY	2381	1032	12.9	18.5	BLOOMINGDALE	2215	1053	3.6	101.1
MONTGOMERY	2438	1032	5.6	35.8	BLOOMINGDALE	2349	1053	11.4	12.4
ELNORA	3266	1033	.7	68.1	CLOVERDALE	2306	1054	.2	70.5
PLAINVILLE	3263	1034	.7	50.8	ROACHDALE	2306	1055	8.7	33.2
KINGMAN	2351	1035	4.1	30.0	ROACHDALE	3232	1055	12.8	36.9
KINGMAN	3229	1035	14.9	12.7	BAINBRIDGE	2212	1056	12.6	23.0
LYONS	3269	1036	13.0	19.7	BAINBRIDGE	2213	1056	6.5	27.2
LYONS	3277	1036	8.4	23.3	CARLISLE	3347	1057	.5	54.1

TABLE A2 (CONTINUED)

NORTH SALEM	3232	1037	.2	77.9	UNIVERSAL	1075	1058	9.2	5.7
CLAYTON	2202	1038	4.3	71.1	UNIVERSAL	2209	1058	20.8	14.4
CLAYTON	2211	1038	11.0	27.0	UNIVERSAL	3234	1058	8.5	24.0
TRAFALGAR	3247	1039	.2	64.5	CAYUGA	3223	1059	.5	82.3
BARGERSVILLE	3245	1040	.5	80.7	DANA	2218	1060	2.0	47.5
OAKTOWN	2341	1041	3.5	29.2	DANA	3224	1060	12.7	22.8
OAKTOWN	2342	1041	10.4	23.2	PERRYSVILLE	3222	1061	1.0	58.9
WHEATLAND	2439	1042	.2	47.2	NEWPORT	2217	1062	8.2	79.9
SANDBORN	3269	1043	.2	57.4	NEWPORT	3224	1062	2.8	37.8
BRUCEVILLE	3265	1044	.2	66.1	PRINCES LAKE	2316	1063	14.0	27.5
NEW MARKET	2222	1045	14.3	27.9	PRINCES LAKE	3247	1063	14.2	6.4
NEW MARKET	2392	1045	4.7	35.6	MARSHALL	2349	1064	4.6	27.5
WAVELAND	3229	1046	.2	49.6	MARSHALL	3231	1064	7.4	15.1
LADOGA	2221	1047	14.1	44.1	RUSSELLVILLE	2396	1065	8.7	20.5
LADOGA	2397	1047	8.5	37.2	RUSSELLVILLE	3230	1065	7.1	14.9
BROOKLYN	3243	1048	5.8	50.4	MEROM	3242	1066	.2	25.4
BROOKLYN	3250	1048	13.4	11.1	COALMONT	3276	1067	1.3	57.6
MORGANTOWN	3248	1049	.2	79.9	COALMONT	3276	1067	3.5	47.1
PARAGON	1051	1050	14.1	3.1	FREELANDVILLE	3268	1068	.2	58.5
PARAGON	2392	1050	18.5	9.4	CRANE	2384	1069	3.0	28.2
HARRODSBURG	2442	1070	22.7	7.9	MONROE CITY	3304	1087	2.0	35.2
HARRODSBURG	3257	1070	19.0	12.0	TROY	3307	1088	.2	53.6
MECCA	2215	1071	8.1	43.3	POSEYVILLE	3286	1089	.2	76.8
MECCA	2348	1071	17.8	18.4	CYNTHIANA	2051	1090	5.2	21.3
FILLMORE	2203	1072	17.4	22.9	CYNTHIANA	3285	1090	2.9	21.8
FILLMORE	2395	1072	11.9	25.7	CYNTHIANA	3286	1090	8.2	25.0
LEWIS	3276	1073	.2	47.9	DALE	2377	1091	.2	62.2
ST. MARY WOODS	1075	1074	7.2	13.7	GRANDVIEW	2372	1092	9.3	18.3
ST. MARY WOODS	2209	1074	4.9	81.3	GRANDVIEW	3305	1092	6.2	15.9
ST. MARY WOODS	3234	1074	24.6	9.0	GRANDVIEW	3307	1092	17.3	6.7
NEW GOSHEN	2209	1075	11.9	24.4	ELBERFELD	2049	1093	2.0	80.2
NEW GOSHEN	3234	1075	17.6	15.1	LYNNVILLE	3292	1094	.2	44.1
MARENGO	3322	1076	.2	54.5	CAMPBELLSBURG	3329	1095	18.1	71.0
ENGLISH	2042	1077	14.8	17.4	CAMPBELLSBURG	3332	1095	20.4	13.4
ENGLISH	3321	1077	2.5	18.4	NEW PEKIN	3328	1096	.5	36.6
MILLTOWN	3323	1078	2.1	32.0	LEAVENWORTH	2424	1097	.2	28.2
MILLTOWN	3324	1078	5.9	20.9	SOMERV-MACKEY	3294	1098	1.0	52.9
HOLLAND	3293	1079	8.7	20.2	CHRISNEY	2373	1099	1.8	14.9
HOLLAND	3299	1079	6.5	25.4	CHRISNEY	2374	1099	4.9	16.3
GEORGETOWN	2039	1080	7.0	46.1	DUBOIS	2380	1100	12.4	18.6
GEORGETOWN	3325	1080	11.7	6.4	DUBOIS	2434	1100	32.2	7.5
GREENVILLE	2429	1081	29.4	8.2	HAYSVILLE	2380	1101	.2	34.7
GREENVILLE	2430	1081	5.2	16.4	VALLONIA	2445	1102	6.0	52.4
FRANCISCO	3295	1082	17.3	21.6	VALLONIA	3333	1102	3.0	15.5
FRANCISCO	3296	1082	5.7	46.4	OTWELL	2438	1103	23.6	11.5
HAZELTOWN	2337	1083	2.1	43.4	OTWELL	3300	1103	1.3	19.3
HAZELTOWN	3303	1083	14.7	3.1	OTWELL	3302	1103	14.8	13.5
PATOKA	2336	1084	5.0	53.3	HATFIELD	1105	1104	7.9	9.4
PATOKA	2337	1084	6.1	21.3	HATFIELD	2371	1104	8.9	19.6
PALMYRA	2431	1085	.2	32.5	HATFIELD	3290	1104	4.2	20.2
MEDORA	2443	1086	6.0	10.1	RICHLAND	2371	1105	7.7	18.4
MEDORA	3333	1086	6.5	35.9	RICHLAND	2417	1105	10.9	19.7
MONROE CITY	3302	1087	16.1	11.8	ST. MEINRAD	2420	1106	0.2	53.0

APPENDIX B

COMPUTER PROGRAMS FOR DETERMINATION OF INTERCITY TRAVEL DESIRE FACTORS

APPENDIX B

COMPUTER PROGRAMS FOR DETERMINATION OF INTERCITY TRAVEL DESIRE FACTORS

B1. Small Trees

The mechanics of Small Trees will be outlined briefly.

Four storage areas, A, B, C, and K were set up where storage areas A and K contained the link and centroid tables respectively. A total of 3,618 link description cards were required to simulate the 1,809 links making up Indiana's highway system. The i^{th} link card consisted of $IANODA_i$ (the A-node in storage A), $IBNODA_i$, and $LABELA_i$ (the distance between the two nodes). The sequence of link cards was subject to only one restriction. All cards having an equal IANODA had to be read into storage consecutively. However, the actual numerical order of IANODA card groups was not important.

The centroid table, consisting of 687 link cards, included only the back link descriptions, i.e., the link from a highway node to a centroid. The sequence of these cards was not important. The forward link cards were read in with each source centroid and were needed to generate the initial connection of the source centroid with the highway network. Each centroid card consisted of IANODK, IBNODK, and DLINK.

Storage area B contained the tree table with three columns designated as IANODB, IBNODB, and LABELB. The IANODB column was a listing of each centroid and node number in the network. Centroid numbers were generated as a consecutive numerical sequence from 656 to 1,106 while the node numbers were generated from the IANODA column of the link table. A total of 1,477 centroids and nodes were thus generated.

IBNODB is the next node on the minimum path node sequence from IANODB to the source centroid while LABELB is the distance from IANODB to the source centroid. In the section on the Basic Minimum Path Algorithm of a previous chapter, it was stated that the label on node i is changed and the node added to a set S provided that:

$$v_i > \min_{j \epsilon S} v_j + d_{ji}$$

or in the context of this section:

$$LABELB_i > \min_{j \epsilon S} LABELB_j + LABELA_{ji}$$

If the label on node i is changed then the following change must also be made:

$$IBNODB_i = IANODB_j$$

Storage area C contains the nodes in the set S designated as IANODC and the label on each node in S, LABELC.

A significant amount of computer time in calculating a tree table is consumed in searching the several node arrays to find the location of certain node numbers. In order to reduce the magnitude of search time, the following substitutions were made after the IANODB array of the tree table had been generated. The first node in the IANODA array of the link table was found in the IANODB array and the subscript of the node substituted for the node number in the IANODA array. For example, if the first node number in the IANODA array was 2,100 and was located in the 557th location of the IANODB array, 557 was substituted for 2,100 in the IANODA array. This same type of substitution was made for each node in the IANODA, IBNODA, IANODK, and IBNODK arrays. This step reduced the necessary search time by about one half. A similar substitution was not made in the tree table node arrays because the original node numbers were needed in Expanded Trees.

A final initialization step was that of setting both the IANODC AND LABELC arrays to zero.

The source centroid and the forward centroid links were then read in and the appropriate changes made in the tree table and the reached nodes placed in C storage.

Subroutine RANK searched for the minimum LABELC distance. The comparison:

$$LABELB_i > \min_{j \in S} LABELC_j + LABELA_{ji}$$

was made with label and node number changes performed as required by the algorithm. The tree table was completed when set S (or the IANODC array) was empty. The tree table was then written on tape for use in Expanded Trees, the procedure then continuing for the balance of the source centroids.

```
     SMALL TREES

$EXECUTE        IBJOB
$IBJOB
$IBFTC INDIAN   SMAP
      REWIND 8
      DIMENSION IANODA(3618).IBNODA(3618).LABFLA(3618).
     1IANODB(1477).IBNODB(1477).LABFLB(1477).IANODC(150).
     1LABFLC(150).IANODK(687).IBNODK(687).DLINK(687)
      COMMON IANODC.LABFLC.KCNOD.KRAM
      REAL LABFLA.LABELB.LABFLC.LABFLD.LABFLS
      READ(5.10)LINKS.NIX.IXNIX.KCNOD
   10 FORMAT(4I5)
      READ(5.11)(IANODB(I).I=1.6)
   11 FORMAT(6I5)
      READ(5.30)(IANODK(I).IBNODK(I).DLINK(I).I=1.687)
      READ(5.30)(IANODA(I).IBNODA(I).LABFLA(I).I=1.LINKS)
   30 FORMAT(2I5.F5.0)
      J=7
      DO 15 I=1.451
      IANODB(J)=IXNIX+I
   15 J=J+1
      IANODB(J)=IANODA(1)
      DO 12 I=1.LINKS
      IF(IANODA(I).EQ.IANODB(J))GO TO 12
      J=J+1
      IANODB(J)=IANODA(I)
   12 CONTINUE
      NODES=J
      WRITE(6.16)IANODA(LINKS).IBNODA(LINKS).IANODB(NODES).NODES.LINKS
   16 FORMAT(1H0.5I7)
      IF(IANODB(NODES).NE.4388)GO TO 300
      IF(IBNODA(LINKS).NE.2157)GO TO 300
      IF(NODES.NE.1477)GO TO 300
      DO 60 I=1.KCNOD
      IANODC(I)=0
   60 LABFLC(I)=0.0
      DO 42 I=1.LINKS
      DO 44 J=1.NODES
      IF(IANODA(I).NE.IANODB(J))GO TO 44
      IANODA(I)=J
      GO TO 42
   44 CONTINUE
   42 CONTINUE
      DO 46 I=1.LINKS
      DO 48 J=1.NODES
      IF(IBNODA(I).NE.IANODB(J))GO TO 48
      IBNODA(I)=J
      GO TO 46
   48 CONTINUE
   46 CONTINUE
      DO 500 J=1.687
      DO 502 K=1.NODES
      IF(IANODK(J).NE.IANODB(K))GO TO 502
      IANODK(J)=K
      GO TO 500
  502 CONTINUE
  500 CONTINUE
      DO 504 J=1.687
```

```
      DO 506 K=1.NODES
      IF(IBNODK(J).NE.IANODB(K))GO TO 506
      IBNODK(J)=K
      GO TO 504
  506 CONTINUE
  504 CONTINUE
 1000 READ(5.70)IHOME.KRIMP
   70 FORMAT(I5.I2)
      KRAM=10
      IF(IHOME.GT.5000)GO TO 300
      DO 50 I=1.NODES
      IBNODB(I)=0
   50 LABELB(I)=9999.0
      DO 100 I=1.NODES
      IF(IANODB(I).NE.IHOME)GO TO 100
      INDEX=I
      GO TO 110
  100 CONTINUE
  110 LABELB(INDEX)=0.0
      KRUM=1
  115 READ(5.30)IANODD.IBNODD.LABELD
      DO 120 I=1.NODES
      IF(IBNODD.NE.IANODB(I))GO TO 120
      INDEX=I
      GO TO 122
  120 CONTINUE
  122 IBNODB(INDEX)=IANODD
      LABELB(INDEX)=LABELD
      IANODC(KRUM)=INDEX
      LABELC(KRUM)=LABELD
      KRUM=KRUM+1
      IF(KRUM.GT.KRIMP)GO TO 161
      GO TO 115
  160 CALL RANK
  161 INC=IANODC(1)
      IF(INC.EQ.0)GO TO 260
      DO 200 I=1.LINKS
      IF(INC.NE.IANODA(I))GO TO 200
      IND=I
      GO TO 210
  200 CONTINUE
      GO TO 255
  210 IANODD=IANODA(IND)
      IBNODD=IBNODA(IND)
      LABELS=LABELA(IND)+LABELC(1)
      IF(LABELS.GE.LABELB(IBNODD))GO TO 250
      LABELB(IBNODD)=LABELS
      IBNODB(IBNODD)=IANODB(IANODD)
      DO 240 I=1.KCNOD
      IF(IANODC(I).NE.0)GO TO 240
      IANODC(I)=IBNODD
      LABELC(I)=LABELS
      IF(I.LE.KRAM)GO TO 250
      KRAM=I
      GO TO 250
  240 CONTINUE
      WRITE(6.244)
  244 FORMAT(1H1.14H OVERFLOW IN C)
```

```
      GO TO 300
  250 IND=IND+1
      IF(INC.EQ.IANODA(IND))GO TO 210
  255 IANODC(1)=0
      LABELC(1)=0
      GO TO 160
  260 WRITE(6.270)IHOME.KRAM
  270 FORMAT(1H0.22H THE STARTING NODE IS .2I7//)
      DO 370 I=1.687
      IXB=IANODK(I)
      IXC=IBNODK(I)
      TOTAL=LABELB(IXB)+DLINK(I)
      IF(TOTAL.GE.LABELB(IXC))GO TO 370
      IBNODB(IXC)=IANODB(IXB)
      LABELB(IXC)=TOTAL
  370 CONTINUE
      WRITE(8.271)IHOME.NODES
  271 FORMAT(2I5)
      WRITE(8.291)(IANODB(I).IBNODB(I).LABELB(I).I=1.NODES)
  291 FORMAT(10(2I4.F5.0))
      WRITE(6.292)
  292 FORMAT(1H .10X.11HON TAPE 10))
  295 GO TO 1000
  300 REWIND 8
      STOP
      END
$IBFTC SUBR1    SMAP
      SUBROUTINE RANK
      DIMENSION IANODC(150).LABELC(150)
      COMMON IANODC.LABELC.KCNOD.KRAM
      REAL JSAVL.LABELC
      JSAVN=0
      JSAVL=10000.0
      DO 400 I=2.KRAM
      IF(IANODC(I).EQ.0)GO TO 400
      IF(JSAVL.LE.LABELC(I))GO TO 400
      JSAVN=IANODC(I)
      JSAVL=LABELC(I)
      IKE=I
  400 CONTINUE
      IF(JSAVN.EQ.0)GO TO 450
      IANODC(1)=JSAVN
      LABELC(1)=JSAVL
      IANODC(IKE)=0
      LABELC(IKE)=0.0
  450 RETURN
      END
$DATA
```

B2. Expanded Trees

The mechanics of Expanded Trees will be outlined briefly.

The first tree table on the tape generated by Small Trees was read in. Because the first centroid number of this tree table was 656, the arrays of the tree table were read into the expanded tree table storage area beginning with the 656th location. The first 655 locations were allocated for the centroids of the four border states and the last 99 for the Interstate nodes including boundary and centroid linked nodes for a total of 2,225 centroids and nodes in the tree table.

All of the border node sets and distance arrays were then read in except for the centroid distance arrays DISTMC, DISTLC, DISTKC, and DISTIC. These were so large they were stored on tape and read into equivalenced storage areas as needed.

All node numbers were then changed to the subscript or location of that node number in the IANODB array of the tree table just as in Small Trees.

After these and other initialization steps had been completed, the first tree table produced by Small Trees was re-read. The minimum path routes from border node to border node were then determined. For instance, the path from a node in H to a node in K, C, or F was determined as follows (refer to Figure 21). If i is the node in H and j a node in H, C, or F, the minimum path is determined as:

$$LABELB_i = \min (LABELB_j + DMBLLL_{ij})$$

This procedure was performed in the program by a series of Do-Loops. The centroid distance arrays were then read one at a time and the minimum path for each determined by the same procedure.

The completed, expanded tree table was then written on tape and the next small tree table read.

EXPANDED TREES

```
$EXECUTE       IBJOB
$IBJOB
$IBFTC EXTREE  SMAP
      REWIND 8
      REWIND 9
      REWIND 10
      DIMENSION IANODB(2225),IBNODB(2225),LABELB(2225),DISTMC(18,125),
     1DISTLC(30,167),DISTKC(13,114),DISTIC(25,249),DISTNC(280),
     1NNATND(280),NACEND(280),DMBLLL(6,30),MBLNOD(6),DKBLLL(2,30),
     1DLBKKK(2,13),KBLNOD(2),DIBKKK(3,13),DKBIII(3,25),IBKNOD(3),
     1MMNODE(18),LLNODE(30),KKNODE(13),IINODE(25),NODE(30),JBRCEN(6),
     1MNATND(5),DISTMN(5,18),LNATND(4),DISTLN(4,30),KNATND(2),
     1DISTKN(2,13),INATND(12),DISTIN(12,25)
      EQUIVALENCE(DISTIC(1,1),DISTKC(1,1),DISTLC(1,1),DISTMC(1,1))
      REAL LABELB
      READ(10,52)IHOME,NODES
   52 FORMAT(2I5)
      READ(10,51)(IANODB(I),IBNODB(I),LABELB(I),I=650,2126)
   51 FORMAT(10(2I4,F5.0))
      REWIND 10
      DO 12 I=1,655
   12 IANODB(I)=I
      READ(5,15)(IANODB(I),I=2127,2225)
   15 FORMAT(20I4)
      READ(5,15)(MMNODE(I),I=1,18)
      READ(5,15)(LLNODE(I),I=1,30)
      READ(5,15)(KKNODE(I),I=1,13)
      READ(5,15)(IINODE(I),I=1,25)
      DO 20 I=1,18
      DO 21 J=1107,2225
      IF(MMNODE(I).NE.IANODB(J))GO TO 21
      MMNODE(I)=J
      GO TO 20
   21 CONTINUE
   20 CONTINUE
      DO 22 I=1,30
      DO 23 J=1107,2225
      IF(LLNODE(I).NE.IANODB(J))GO TO 23
      LLNODE(I)=J
      GO TO 22
   23 CONTINUE
   22 CONTINUE
      DO 24 I=1,13
      DO 25 J=1107,2225
      IF(KKNODE(I).NE.IANODB(J))GO TO 25
      KKNODE(I)=J
      GO TO 24
   25 CONTINUE
   24 CONTINUE
      DO 26 I=1,25
      DO 27 J=1107,2225
      IF(IINODE(I).NE.IANODB(J))GO TO 27
      IINODE(I)=J
      GO TO 26
   27 CONTINUE
   26 CONTINUE
      DO 130 I=1,6
```

```
      READ(5,53)MBLNOD(I)
  130 READ(5,54)(DMBLLL(I,J),J=1,30)
   53 FORMAT(I5)
   54 FORMAT(20F4.0)
      DO 132 I=1,2
      READ(5,53)KBLNOD(I)
      READ(5,54)(DKBLLL(I,J),J=1,30)
  132 READ(5,54)(DLBKKK(I,J),J=1,13)
      DO 134 I=1,3
      READ(5,53)IBKNOD(I)
      READ(5,54)(DIBKKK(I,J),J=1,13)
  134 READ(5,54)(DKBIII(I,J),J=1,25)
      DO 30 I=1,6
      DO 31 J=1107,2225
      IF(MBLNOD(I).NE.IANODB(J))GO TO 31
      MBLNOD(I)=J
      GO TO 30
   31 CONTINUE
   30 CONTINUE
      DO 32 I=1,2
      DO 33 J=1107,2225
      IF(KBLNOD(I).NE.IANODB(J))GO TO 33
      KBLNOD(I)=J
      GO TO 32
   33 CONTINUE
   32 CONTINUE
      DO 34 I=1,3
      DO 35 J=1107,2225
      IF(IBKNOD(I).NE.IANODB(J))GO TO 35
      IBKNOD(I)=J
      GO TO 34
   35 CONTINUE
   34 CONTINUE
      DO 40 I=1,5
      READ(5,53)MNATND(I)
   40 READ(5,54)(DISTMN(I,J),J=1,18)
      DO 41 I=1,4
      READ(5,53)LNATND(I)
   41 READ(5,54)(DISTLN(I,J),J=1,30)
      DO 42 I=1,2
      READ(5,53)KNATND(I)
   42 READ(5,54)(DISTKN(I,J),J=1,13)
      DO 43 I=1,12
      READ(5,53)INATND(I)
   43 READ(5,54)(DISTIN(I,J),J=1,25)
      DO 44 I=1,5
      DO 45 J=1107,2225
      IF(MNATND(I).NE.IANODB(J))GO TO 45
      MNATND(I)=J
      GO TO 44
   45 CONTINUE
   44 CONTINUE
      DO 46 I=1,4
      DO 47 J=1107,2225
      IF(LNATND(I).NE.IANODB(J))GO TO 47
      LNATND(I)=J
      GO TO 46
   47 CONTINUE
   46 CONTINUE
      DO 48 I=1,2
      DO 49 J=1107,2225
```

```
      IF(KNATND(I).NE.IANODB(J))GO TO 49
      KNATND(I)=J
      GO TO 48
   49 CONTINUE
   48 CONTINUE
      DO 60 I=1,12
      DO 61 J=1107,2225
      IF(INATND(I).NE.IANODB(J))GO TO 61
      INATND(I)=J
      GO TO 60
   61 CONTINUE
   60 CONTINUE
      READ(5,57)(NNATND(I),NACEND(I),DISTNC(I),I=1,280)
   57 FORMAT(2I5,F5.0)
      DO 62 I=1,280
      DO 63 J=1107,2225
      IF(NNATND(I).NE.IANODB(J))GO TO 63
      NNATND(I)=J
      GO TO 62
   63 CONTINUE
   62 CONTINUE
      DO 64 I=1,280
      DO 65 J=1107,2225
      IF(NACEND(I).NE.IANODB(J))GO TO 65
      NACEND(I)=J
      GO TO 64
   65 CONTINUE
   64 CONTINUE
      READ(5,58)(JBRCEN(I),I=1,6)
   58 FORMAT(6I4)
      WRITE(6,58)(JBRCEN(I),I=1,6)
      IF(JBRCEN(1).NE.14)GO TO 300
      NNODES=2225
 1000 READ(10,52)IHOME,NODES
      DO 101 I=1,2225
      IBNODB(I)=0
  101 LABELB(I)=9999.
      READ(10,51)(IANODB(I),IBNODB(I),LABELB(I),I=650,2126)
      DO 103 J=1,6
      JTRY=JBRCEN(J)
      JTRX=649+J
      IBNODB(JTRY)=IBNODB(JTRX)
      LABELB(JTRY)=LABELB(JTRX)
      IBNODB(JTRX)=0
      LABELB(JTRX)=9999.
  103 IANODB(JTRX)=JTRX
  201 ITCHY=0
      DO 112 I=1,6
      IXB=MBLNOD(I)
      DO 112 J=1,30
      IXC=LLNODE(J)
      TOTAL=LABELB(IXC)+DMBLLL(I,J)
      IF(TOTAL.GE.LABELB(IXB))GO TO 112
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
      ITCHY=ITCHY+1
  112 CONTINUE
      IF(ITCHY.NE.0)GO TO 201
  202 ITCHY=0
      DO 114 I=1,2
      IXB=KBLNOD(I)
```

```
      DO 115 J=1,30
      IXC=LLNODE(J)
      TOTAL=LABELB(IXC)+DKBLLL(I,J)
      IF(TOTAL.GE.LABELB(IXB))GO TO 115
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
      ITCHY=ITCHY+1
  115 CONTINUE
      DO 116 J=1,13
      IXC=KKNODE(J)
      TOTAL=LABELB(IXC)+DLBKKK(I,J)
      IF(TOTAL.GE.LABELB(IXB))GO TO 116
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
      ITCHY=ITCHY+1
  116 CONTINUE
  114 CONTINUE
      IF(ITCHY.NE.0)GO TO 202
  203 ITCHY=0
      DO 117 I=1,3
      IXB=IBKNOD(I)
      DO 118 J=1,13
      IXC=KKNODE(J)
      TOTAL=LABELB(IXC)+DIBKKK(I,J)
      IF(TOTAL.GE.LABELB(IXB))GO TO 118
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
      ITCHY=ITCHY+1
  118 CONTINUE
      DO 119 J=1,25
      IXC=IINODE(J)
      TOTAL=LABELB(IXC)+DKBIII(I,J)
      IF(TOTAL.GE.LABELB(IXB))GO TO 119
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
      ITCHY=ITCHY+1
  119 CONTINUE
  117 CONTINUE
      IF(ITCHY.NE.0)GO TO 203
      DO 120 I=1,5
      IXB=MNATND(I)
      DO 120 J=1,18
      IXC=MMNODE(J)
      TOTAL=LABELB(IXC)+DISTMN(I,J)
      IF(TOTAL.GE.LABELB(IXB))GO TO 120
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
  120 CONTINUE
      DO 122 I=1,4
      IXB=LNATND(I)
      DO 122 J=1,30
      IXC=LLNODE(J)
      TOTAL=LABELB(IXC)+DISTLN(I,J)
      IF(TOTAL.GE.LABELB(IXB))GO TO 122
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
  122 CONTINUE
      DO 124 I=1,2
      IXB=KNATND(I)
      DO 124 J=1,13
      IXC=KKNODE(J)
```

```
      TOTAL=LABELB(IXC)+DISTKN(I,J)
      IF(TOTAL.GE.LABELB(IXB))GO TO 124
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
  124 CONTINUE
      DO 126 I=1,12
      IXB=INATND(I)
      DO 126 J=1,25
      IXC=IINODE(J)
      TOTAL=LABELB(IXC)+DISTIN(I,J)
      IF(TOTAL.GE.LABELB(IXB))GO TO 126
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
  126 CONTINUE
      DO 128 I=1,280
      IXB=NACEND(I)
      IXC=NNATND(I)
      TOTAL=LABELB(IXC)+DISTNC(I)
      IF(TOTAL.GE.LABELB(IXB))GO TO 128
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
  128 CONTINUE
   55 FORMAT(24F5.0)
  900 READ(8,52)NIX,MNIX
      DO 140 I=1,NIX
      READ(8,53)NODE(I)
  140 READ(8,55)(DISTMC(I,J),J=1,MNIX)
      DO 142 I=1,125
      IXB=I
      DO 142 J=1,18
      IXC=MMNODE(J)
      TOTAL=LABELB(IXC)+DISTMC(J,I)
      IF(TOTAL.GE.LABELB(IXB))GO TO 142
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
  142 CONTINUE
      READ(8,52)NIX,MNIX
      DO 144 I=1,NIX
      READ(8,53)NODE(I)
  144 READ(8,55)(DISTLC(I,J),J=1,MNIX)
      DO 146 I=1,167
      IXB=I+125
      DO 146 J=1,30
      IXC=LLNODE(J)
      TOTAL=LABELB(IXC)+DISTLC(J,I)
      IF(TOTAL.GE.LABELB(IXB))GO TO 146
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
  146 CONTINUE
      READ(8,52)NIX,MNIX
      DO 148 I=1,NIX
      READ(8,53)NODE(I)
  148 READ(8,55)(DISTKC(I,J),J=1,MNIX)
      DO 150 I=1,114
      IXB=I+292
      DO 150 J=1,13
      IXC=KKNODE(J)
      TOTAL=LABELB(IXC)+DISTKC(J,I)
      IF(TOTAL.GE.LABELB(IXB))GO TO 150
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
```

```
  150 CONTINUE
      READ(8,52)NIX,MNIX
      DO 152 I=1,NIX
      READ(8,53)NODE(I)
  152 READ(8,55)(DISTIC(I,J),J=1,MNIX)
      DO 154 I=1,249
      IXB=I+406
      DO 154 J=1,25
      IXC=INODE(J)
      TOTAL=LABELB(IXC)+DISTIC(J,I)
      IF(TOTAL.GE.LABELB(IXB))GO TO 154
      IBNODB(IXB)=IANODB(IXC)
      LABELB(IXB)=TOTAL
  154 CONTINUE
      REWIND 8
      WRITE(6,301)IHOME
  301 FORMAT(1H1,10X,12HHOME NODE IS,I5///)
      WRITE(9,52)IHOME,NNODES
      WRITE(9,302)(IANODB(I),IBNODB(I),LABELB(I),I=1,NNODES)
  302 FORMAT(10(2I4,F5.0))
      WRITE(6,303)
  303 FORMAT(1H0,20X,22HTREE TABLE ON TAPE 262////)
      IF(IHOME.EQ.727)GO TO 300
      GO TO 1000
  300 REWIND 8
      REWIND 9
      REWIND 10
      STOP
      END
$DATA
```

B3. Trades

The mechanics of Trades will be outlined briefly.

After all the data had been read in, all node numbers were changed to the subscript of their location in the IANODB column of the expanded tree table. This included both the IANODB and IBNODB columns of the tree table.

The cumulative totals of ITDF's calculated were kept for the 2,510 centroid and highway links making up the Indiana network. Each link was described by the subscripts representing the two end nodes.

The path between the source centroid and another centroid was traced, the path being stored as a series of numbers from 1 to 2,510, each representing one of the Indiana centroid or highway links. The travel desire factor was calculated and assigned to each of the links on the path. When all factors had been calculated, the population of the source centroid was changed to zero and the next source centroid with its associated expanded tree table read.

The calculation of the travel desire factors were subject to the following restrictions:

1. Only cities of greater than 5,000 had interactions with Interstate cities.

2. Cities of less than 1,000 had interactions only with cities within 150 miles of their location.

3. Cities between 1,000 and 5,000 had interactions with other cities of less than 5,000 only if within 300 miles of their location.

4. The population of the larger city of a pair of cities was not allowed to be greater than 10 times the population of the smaller city.

These restrictions were imposed in an attempt to overcome some objections to a gravity model approach to travel synthesis as outlined in an earlier chapter, "Study Procedure," the principal objection being that use of this approach allows a virtually unlimited trip generation capability of each centroid. The only basis for the numerical value of the imposed limitations was that they appeared reasonable.

TRADES

```
$EXECUTE        IBJOB
$IBJOB
$IBFTC TRADES  SMAP
      REWIND 8
      REWIND 9
      DIMENSION IANODB(2225),IBNODB(2225),LABELB(2225),
     1IBAKND(100),NUMBER(99),POPIN(1106),POPEX(181),NODEX(181),
     1DISTEX(181),NODA(2510),NODB(2510),ALPHAD(2510),ALPHAT(2510),
     1ALPHAF(2510)
      DIMENSION SAVEX(181)
      COMMON IXB,JEM,JIM,IHOME,NODES
      REAL LABELB
      READ(8,301)IHOME,NODES
      READ(8,302)(IANODB(I),IBNODB(I),LABENB(I),I=1,NODES)
      REWIND 8
      IKNKNT=0
      READ(5,51)(POPIN(I),I=1,1106)
   51 FORMAT(6X,F7.0)
      READ(5,52)(NODEX(I),DISTEX(I),POPEX(I),I=1,181)
   52 FORMAT(I5,2F9.0)
      DO 60 I=1,1106
   60 POPIN(I)=SQRT(POPIN(I))
      DO 62 I=1,2510
      ALPHAD(I)=0.0
      ALPHAT(I)=0.0
   62 ALPHAF(I)=0.0
      READ(5,50)(NODA(I),NODB(I),I=1,702)
      READ(5,50)(NODA(I),NODB(I),I=703,2510)
   50 FORMAT(20I4)
      WRITE(6,25)NODEX(181),NODB(2510)
   25 FORMAT(1H0,5X,2I10)
      IF(NODEX(181).NE.1785)GO TO 300
      IF(NODB(2510).NE.2068)GO TO 300
      DO 70 I=1,181
      DO 72 J=2127,2225
      IF(NODEX(I).NE.IANODB(J))GO TO 72
      NODEX(I)=J
      GO TO 70
   72 CONTINUE
   70 CONTINUE
      DO 75 I=1,181
   75 SAVEX(I)=POPEX(I)
 1000 READ(8,301)IHOME,NODES
  301 FORMAT(2I5)
      READ(8,302)(IANODB(I),IBNODB(I),LABELB(I),I=1,NODES)
  302 FORMAT(10(2I4,F5.0))
      DO 80 I=1,2225
      IF(IBNODB(I).LT.1107)GO TO 80
      DO 82 J=1107,2225
      IF(IBNODB(I).NE.IANODB(J))GO TO 82
      IBNODB(I)=J
      GO TO 80
   82 CONTINUE
   80 CONTINUE
      DO 90 I=1107,2225
   90 IANODB(I)=I
      DO 95 I=1,181
```

```
   95 POPEX(I)=SAVEX(I)
      POPHOM=POPIN(IHOME)
      DO 100 I=1,1106
      IF(IBNODB(I).EQ.0)GO TO 100
      IF(POPIN(I).EQ.0.0)GO TO 100
      DISTER=LABELB(I)
      IF(POPIN(I).LE.31.7.AND.DISTER.GT.150.5)GO TO 100
      INCRMT=I
      DO 110 K=1,100
      KOUNT=K
      IBAKND(K)=INCRMT
      IF(IBNODB(INCRMT).EQ.0)GO TO 130
  110 INCRMT=IBNODB(INCRMT)
      WRITE(6,134)KOUNT
  134 FORMAT(1H1,I10,5HKOUNT)
      GO TO 300
  130 IX=0
      DO 140 K=2,KOUNT
      IXB=IBAKND(K-1)
      IXC=IBAKND(K)
      IF(IXB.LT.IXC)GO TO 141
      IXB=IBAKND(K)
      IXC=IBAKND(K-1)
  141 IF(IXB.GT.2067)GO TO 140
      CALL INDEXR
      DO 160 J=JEM,JIM
      IF(IXB.NE.NODA(J))GO TO 160
      JX=J
  162 IF(IXC.NE.NODB(JX))GO TO 161
      IX=IX+1
      NUMBER(IX)=JX
      GO TO 140
  161 JX=JX+1
      IF (IXB .EQ. NODA(JX)) GO TO 162
      GO TO 140
160   CONTINUE
140   CONTINUE
  170 II=I
      ISAME=IBNODB(I)
      DO 180 N=II,655
      IF(IBNODB(N).NE.ISAME)GO TO 180
      IBNODB(N)=0
      IF(IX.EQ.0)GO TO 180
      POPHOM=POPIN(IHOME)
      POPULA=POPIN(N)
      DISTER=LABELB(N)
      IF(POPULA.LT.31.7.AND.DISTER.GT.150.5)GO TO 180
      IF(POPULA.GT.(3.17*POPHOM))POPULA=3.17*POPHOM
      IF(POPHOM.GT.(3.17*POPULA))POPHOM=3.17*POPULA
      SIGMAA=POPULA*POPHOM
      SIGMAB=SIGMAA/DISTER
      SIGMAC=SIGMAB/DISTER
      IKNKNT=IKNKNT+1
      DO 190 M=1,IX
      JJ=NUMBER(M)
      ALPHAO(JJ)=ALPHAO(JJ)+SIGMAA
      ALPHAT(JJ)=ALPHAT(JJ)+SIGMAB
  190 ALPHAF(JJ)=ALPHAF(JJ)+SIGMAC
  180 CONTINUE
  100 CONTINUE
      IF(POPIN(IHOME)**2.LT.5000.)GO TO 299
```

```
1200 DO 220 I=2127,2212
     IF(IBNODB(I).EQ.0)GO TO 220
     DO 222 N=1,181
     IF(NODEX(N).NE.I)GO TO 222
     IF(POPEX(N).EQ.0.)GO TO 220
     GO TO 223
 222 CONTINUE
 223 INCRMT=I
     DO 225 K=1,100
     KOUNT=K
     IBAKND(K)=INCRMT
     IF(IBNODB(INCRMT).EQ.0)GO TO 230
 225 INCRMT=IBNODB(INCRMT)
     WRITE(6,134)KOUNT
     GO TO 300
 230 IX=0
     DO 240 K=2,KOUNT
     IXB=IBAKND(K-1)
     IXC=IBAKND(K)
     IF(IXB.LT.IXC)GO TO 241
     IXB=IBAKND(K)
     IXC=IBAKND(K-1)
 241 IF(IXB.GT.2067)GO TO 240
     CALL INDEXR
     DO 260 J=JEM,JIM
     IF(IXB.NE.NODA(J))GO TO 260
     JX=J
 262 IF(IXC.NE.NODB(JX))GO TO 261
     IX=IX+1
     NUMBER(IX)=JX
     GO TO 240
 261 JX=JX+1
     IF(IXB.EQ.NODA(JX))GO TO 262
     GO TO 240
 260 CONTINUE
 240 CONTINUE
     II=I
     ISAME=IBNODB(I)
     DO 280 N=II,2212
     IF(IBNODB(N).NE.ISAME)GO TO 280
     IF(IX.EQ.0)GO TO 280
     DO 282 K=1,181
     IF(NODEX(K).NE.N)GO TO 282
     KK=K
     GO TO 283
 282 CONTINUE
 283 DO 284 K=KK,181
     IF(NODEX(K).NE.N)GO TO 280
     POPHOM=POPIN(IHOME)
     POPULA=POPEX(K)
     POPEX(K)=0.0
     DISTER=LABELB(N)+DISTEX(K)
     SIGMAA=POPULA*POPHOM
     SIGMAB=SIGMAA/DISTER
     SIGMAC=SIGMAB/DISTER
     IKNKNT=IKNKNT+1
     DO 290 M=1,IX
     JJ=NUMBER(M)
     ALPHAO(JJ)=ALPHAO(JJ)+SIGMAA
     ALPHAT(JJ)=ALPHAT(JJ)+SIGMAB
 290 ALPHAF(JJ)=ALPHAF(JJ)+SIGMAC
```

```
  284 CONTINUE
  280 CONTINUE
  220 CONTINUE
  299 WRITE(6,390)IHOME
  390 FORMAT(1H0,10X,6HIHOME=,I5)
      POPIN(IHOME)=0.0
      IF(IHOME.EQ.727)GO TO 1100
      GO TO 1C00
 1100 WRITE(6,400)
  400 FORMAT(1H1,5X,31HINTERCITY TRAVEL DESIRE FACTORS//)
      WRITE(9,410)(ALPHAO(I),ALPHAT(I),ALPHAF(I),I=1,2510)
  410 FORMAT(6(1PE20.9))
      WRITE(6,420)
  420 FORMAT(1H0,20X,18HFACTORS ON TAPE 6 1)
      DO 1050 I=1,2510
 1050 WRITE(6,1060)I,ALPHAO(I),ALPHAT(I),ALPHAF(I)
 1060 FORMAT(I10,3(1PE20.9))
  300 REWIND 8
      REWIND 9
      WRITE(6,993)IKNKNT
  993 FORMAT(1H1,10X,7HIKNKNT=,I10)
      STOP
      END
$IBFTC SUBP1
      SUBROUTINE INDEXR
      COMMCN IXB,JEM,JIM,IHOME,NODES
      JIM=2510
      IF(IXB.GT.1106)GO TO 148
      IF(IXB.GT. 721)GO TO 142
      JEM=1
      JIM=100
      GO TO 150
  142 IF(IXB.GT. 789)GO TO 143
      JEM=101
      GO TO 150
  143 IF(IXB.GT. 865)GO TO 144
      JEM=201
      GO TO 150
  144 IF(IXB.GT. 927)GO TO 145
      JEM=302
      GO TO 150
  145 IF(IXB.GT. 986)GO TO 146
      JEM=403
      GO TO 150
  146 IF(IXB.GT.1049)GO TO 147
      JEM=502
      GO TO 150
  147 JEM=602
      GO TO 150
  148 IF(IXB.GT.1396)GO TO 156
      IF(IXB.GT.1148)GO TO 149
      JEM=703
      GO TO 150
  149 IF(IXB.GT.1188)GO TO 151
      JEM=802
      GO TO 150
  151 IF(IXB.GT.1222)GO TO 152
      JEM=901
      GO TO 150
  152 IF(IXB.GT.1262)GO TO 153
      JEM=1000
```

```
      GO TO 150
  153 IF(IXB.GT.1311)GO TO 154
      JEM=1100
      GO TO 150
  154 IF(IXB.GT.1354)GO TO 155
      JEM=1199
      GO TO 150
  155 JEM=1298
      GO TO 150
  156 IF(IXB.GT.1442)GO TO 157
      JEM=1404
      GO TO 150
  157 IF(IXB.GT.1486)GO TO 158
      JEM=1503
      GO TO 150
  158 IF(IXB.GT.1540)GO TO 159
      JEM=1605
      GO TO 150
  159 IF(IXB.GT.1583)GO TO 163
      JEM=1709
      GO TO 150
  163 IF(IXB.GT.1622)GO TO 164
      JEM=1808
      GO TO 150
  164 IF(IXB.GT.1663)GO TO 165
      JEM=1908
      GO TO 150
  165 IF(IXB.GT.1732)GO TO 166
      JEM=2008
      GO TO 150
  166 IF(IXB.GT.1822)GO TO 167
      JEM=2111
      GO TO 150
  167 IF(IXB.GT.1891)GO TO 168
      JEM=2210
      GO TO 150
  168 IF(IXB.GT.1984)GO TO 169
      JEM=2311
      GO TO 150
  169 JEM=2411
  150 RETURN
      END
$DATA
```

B4. Border Trees

The mechanics of Border Trees will be outlined briefly.

After the distance arrays and node sets had been read in, the IANODB array of the tree table was generated and all node numbers changed to the subscript of their location in the IANODB array.

The distance arrays were called in the sequence listed in Table B1 depending upon the border state in which the source centroid was located. Table B1 shows the operation performed with each distance array. For instance, in the sequence for a source centroid in Michigan, the first time DISTML is used, every node in B is given the opportunity to be the next node on the minimum path node sequence to the source centroid from every node in C. The second time DISTML is used, every node in C is given the opportunity to function similarly for every node in B.

The nature of the operation is given by the entries in the "From Node" and "To Node" columns of Table B1 for each distance array listed. The operations performed on each distance array, except for the first one, are repeated until no label changes for any node are made in an entire sequence.

At this point, the tree table and the minimum path node sequences from each centroid to the source centroid were written and the next source centroid was read.

Table B1. Distance Array Sequence in Border Trees-By State.

Michigan			Ohio		
Distance Arrays	Node Sets		Distance Arrays	Node Sets	
	From Node	To Node		From Node	To Node
DISTMC	B,H	M*	DISTLC	F,C,H	L*
DISTML	C	B	DMBLLL	H	F,C,H
DMBLLL	F,C,H	H	DKBLLL	F	F,C,H
DISTML	B	C	DMBLLL	F,C,H	H
DMBLLL	H	F,C,H	DKBLLL	F,C,H	F
DKBLLL	F	F,C,H	DISTML	B	C
DISTMI	E	B	DISTLI	E	C
DISTLI	E	C	DISTLK	D	C
DISTMK	D	B	DISTML	C	B
DISTLK	D	C	DISTMK	D	B
DKBIII	G	E,G	DISTMI	E	B
DISTKI	D	E	DLBKKK	G,D,F	F
DLBKKK	G,D,F	F	DLBKKK	F	G,D,F
DKBIII	E,G	G	DISTLK	C	D
DISTKI	E	D	DISTMK	B	D
DIBKKK	G	G,D,F	DISTKI	E	D
DIBKKK	G,D,F	G	DIBKKK	G	G,D,F
DLBKKK	F	G,D,F	DISTMI	B	E
DKBLLL	F,C,H	F	DISTLI	C	E
DISTLK	C	D	DISTKI	D	E
DISTLI	C	E	DKBIII	G	E,G
DISTMI	B	E	DKBIII	E,G	G
DISTMK	B	D	DIBKKK	G,D,F	G
DISTLC	L*	F,C,H	DISTKC	K*	G,D,F
DISTKC	K*	G,D,F	DISTIC	I*	E,G
DISTIC	I*	E,G	DISTMN	N	B,H
DISTMN	N	B,H	DISTLN	N	F,C,H
DISTLN	N	F,C,H	DISTKN	N	G,D,F
DISTKN	N	G,D,F	DISTIN	N	E,G
DISTIN	N	E,G	DISTNC	N*	N
DISTNC	N*	N	DLBJLJ	C	C
DMBJMJ	B	B	DMBJMJ	B	B
DLBJLJ	C	C	DKBJKJ	D	D
DKBJKJ	D	D	DIBJIJ	E	E
DIBJIJ	E	E			

RETURN TO DISTML

RETURN TO DMBLLL

*Centroids

Table B1. Continued.

Kentucky			Illinois		
Distance Arrays	Node Sets		Distance Arrays	Node Sets	
	From Node	To Node		From Node	To Node
DISTKC	G,D,F	K*	DISTIC	E,G	I*
DLBKKK	F	G,D,F	DKBIII	G	E,G
DIBKKK	G	G,D,F	DKBIII	E,G	G
DLBKKK	G,D,F	F	DISTKI	D	E
DIBKKK	G,D,F	G	DISTLI	C	E
DISTLK	C	D	DISTMI	B	E
DISTMK	B	D	DIBKKK	G,D,F	G
DISTKI	E	D	DIBKKK	G	G,D,F
DKBLLL	F,C,H	F	DISTKI	E	D
DISTLK	D	C	DISTMK	B	D
DISTML	B	C	DISTLK	C	D
DISTLI	E	C	DLBKKK	F	G,D,F
DKBLLL	F	F,C,H	DISTMI	E	B
DMBLLL	H	F,C,H	DISTMK	D	B
DKBIII	E,G	G	DISTML	C	B
DKBIII	G	E,G	DISTLI	E	C
DISTKI	D	E	DISTML	B	C
DISTLI	C	E	DISTLK	D	C
DISTMI	B	E	DMBLLL	H	F,C,H
DMBLLL	F,C,H	H	DKBLLL	F	F,C,H
DISTMK	D	B	DLBKKK	G,D,F	F
DISTMI	E	B	DMBLLL	F,C,H	H
DISTML	C	B	DKBLLL	F,C,H	F
DISTIC	I*	E,G	DISTMN	N	B,H
DISTMN	N	B,H	DISTLN	N	F,C,H
DISTLN	N	F,C,H	DISTKN	N	G,D,F
DISTKN	N	G,D,F	DISTIN	N	E,G
DISTIN	N	E,G	DISTNC	N*	N
DISTNC	N*	N	DIBJIJ	E	E
DKBJKJ	D	D	DKBJKJ	D	D
DLBJLJ	C	C	DMBJMJ	B	B
DIBJIJ	E	E	DLBJLJ	C	C
DMBJMJ	B	B			
RETURN TO DLBKKK			RETURN TO DKBIII		

*Centroids

BORDER TREES

MICHIGAN AS BORDER STATE

```
$EXECUTE       IBJOB
$IBJOB
$IBFTC EXTCEN   SMAP
      DIMENSION IANODB(360),IBNODB(360),LABENB(360),MCENTR(39),MMNODE(18
     1),DISTMC(18,39),MMNOBE(18),LLNODE(30),LLNOBE(30),LCENTR(65),DISTLC
     1(30,65),KKNODE(13),KKNOBE(13),KCENTR(34),DISTKC(13,34),IINODE(25),
     1IINOBE(25),ICENTR(98),DISTIC(25,98),MBJNOD(11),MBJNOB(11),LBJNOD(2
     12),LBJNOB(22),KBJNOD(8),KBJNOB(8),IBJNOD(22),IBJNOB(22),DISTML(11,
     122),DISTMK(11,8),DISTMI(11,22),DISTLK(22,8),DISTLI(22,22),DISTKI(8
     1,22),MBLNOD(6),MBLNOB(6),KBLNOD(2),KBLNOB(2),LBKNOD(2),LBKNOB(2),I
     1BKNOD(3),IBKNOB(3),KBINOD(3),KBINOB(3),DMBLLL(6,30),DKBLLL(2,30),D
     1LBKKK(2,13),DIBKKK(3,13),DKBIII(3,25)
      DIMENSION MNATND(5),MNATNB(5),DISTMN(5,18),LNATND(4),LNATNB(4),DIS
     1TLN(4,30),KNATND(2),KNATNB(2),DISTKN(2,13),INATND(12),INATNB(12)
      DIMENSION DISTIN(12,25),NNATND(280),NNATNB(280),NACEND(280),NACENB
     1(280),DISTNC(280),LENGTH(360)
      DIMENSION DMBJMJ(18,18),DLBJLJ(22,22),DKBJKJ(8,8),DIBJIJ(22,22)
      COMMON IHOME,NODES,IANODB,IBNODB,LABENB,NIX,NOX,KIX
      REAL LABENB
COMMENT  LABENB EQUIVALENT LABELB
      INDEX=0
      NODES=360
      NIX=198
      NOX=NIX+1
      KIX=NIX+86
      IXNIX = KIX - 1
      IF(NIX.EQ.1)GO TO 10
      READ(5,51)(IANODB(I),I=2,NIX)
   10 READ(5,51)(IANODB(I),I=NOX,NODES)
   51 FORMAT(20I4)
      READ(5,51)(MCENTR(I),I=1,39)
      DO 60 I=1,18
      READ(5,52)MMNODE(I),MNIX
   60 READ(5,56)(DISTMC(I,J),J=1,MNIX)
   52 FORMAT(2I5)
   56 FORMAT(16F5.0)
      READ(5,51)(LCENTR(I),I=1,65)
      DO 70 I=1,30
      READ(5,52)LLNODE(I),LNIX
   70 READ(5,56)(DISTLC(I,J),J=1,LNIX)
      READ(5,51)(KCENTR(I),I=1,34)
      DO 80 I=1,13
      READ(5,52)KKNODE(I),KNIX
   80 READ(5,56)(DISTKC(I,J),J=1,KNIX)
      READ(5,51)(ICENTR(I),I=1,98)
      DO 90 I=1,25
      READ(5,52)IINODE(I),INIX
   90 READ(5,56)(DISTIC(I,J),J=1,INIX)
      DO 100 I=1,11
      READ(5,53)MBJNOD(I)
   53 FORMAT(I5)
      READ(5,56)(DISTML(I,J),J=1,22)
      READ(5,56)(DISTMK(I,J),J=1,8)
  100 READ(5,56)(DISTMI(I,J),J=1,22)
      DO 110 I=1,22
```

```
      READ(5,53)LBJNOD(I)
      READ(5,56)(DISTLK(I,J),J=1,8)
  110 READ(5,56)(DISTLI(I,J),J=1,22)
      DO 120 I=1,8
      READ(5,53)KBJNOD(I)
  120 READ(5,56)(DISTKI(I,J),J=1,22)
      READ(5,51)(IBJNOD(I),I=1,22)
      DO 130 I=1,6
      READ(5,53)MBLNOD(I)
  130 READ(5,54)(DMBLLL(I,J),J=1,30)
   54 FORMAT(20F4.0)
      DO 131 I=1,2
      READ(5,53)KBLNOD(I)
  131 READ(5,54)(DKBLLL(I,J),J=1,30)
      DO 132 I=1,2
      READ(5,53)LBKNOD(I)
  132 READ(5,54)(DLBKKK(I,J),J=1,13)
      DO 133 I=1,3
      READ(5,53)IBKNOD(I)
  133 READ(5,54)(DIBKKK(I,J),J=1,13)
      DO 134 I=1,3
      READ(5,53)KBINOD(I)
  134 READ(5,54)(DKBIII(I,J),J=1,25)
      DO 601 I=1,5
      READ(5,53)MNATND(I)
  601 READ(5,54)(DISTMN(I,J),J=1,18)
      DO 602 I=1,4
      READ(5,53)LNATND(I)
  602 READ(5,54)(DISTLN(I,J),J=1,30)
      DO 603 I=1,2
      READ(5,53)KNATND(I)
  603 READ(5,54)(DISTKN(I,J),J=1,13)
      DO 604 I=1,12
      READ(5,53)INATND(I)
  604 READ(5,54)(DISTIN(I,J),J=1,25)
      READ(5,57)(NNATND(I),NACEND(I),DISTNC(I),I=1,280)
   57 FORMAT(2I5,F5.0)
      DO 605 I=1,18
  605 READ(5,59)(DMBJMJ(I,J),J=1,18)
      DO 606 I=1,22
  606 READ(5,59)(DLBJLJ(I,J),J=1,22)
      DO 607 I=1,8
  607 READ(5,59)(DKBJKJ(I,J),J=1,8)
      DO 608 I=1,22
  608 READ(5,59)(DIBJIJ(I,J),J=1,22)
   59 FORMAT(22F3.0)
      WRITE(6,125)KBINOD(3),DKBIII(3,25)
  125 FORMAT(1H0,I5,F10.0)
      IF(KBINOD(3).NE.4303)GO TO 300
      IF(DKBIII(3,25).NE.386.)GO TO 300
      DO 140 I=1,18
      DO 141 J=NOX,NODES
      IF(MMNODE(I).NE.IANODB(J))GO TO 141
      MMNOBE(I)=J
      GO TO 140
  141 CONTINUE
  140 CONTINUE
      DO 142 I=1,30
      DO 143 J=NOX,NODES
      IF(LLNODE(I).NE.IANODB(J))GO TO 143
      LLNOBE(I)=J
```

```
      GO TO 142
  143 CONTINUE
  142 CONTINUE
      DO 144 I=1,13
      DO 145 J=NOX,NODES
      IF(KKNODE(I).NE.IANODB(J))GO TO 145
      KKNOBE(I)=J
      GO TO 144
  145 CONTINUE
  144 CONTINUE
      DO 146 I=1,25
      DO 147 J=NOX,NODES
      IF(IINODE(I).NE.IANODB(J))GO TO 147
      IINOBE(I)=J
      GO TO 146
  147 CONTINUE
  146 CONTINUE
      DO 148 I=1,11
      DO 149 J=NOX,NODES
      IF(MBJNOD(I).NE.IANODB(J))GO TO 149
      MBJNOB(I)=J
      GO TO 148
  149 CONTINUE
  148 CONTINUE
      DO 150 I=1,22
      DO 151 J=NOX,NODES
      IF(LBJNOD(I).NE.IANODB(J))GO TO 151
      LBJNOB(I)=J
      GO TO 150
  151 CONTINUE
  150 CONTINUE
      DO 152 I=1,8
      DO 153 J=NOX,NODES
      IF(KBJNOD(I).NE.IANODB(J))GO TO 153
      KBJNOB(I)=J
      GO TO 152
  153 CONTINUE
  152 CONTINUE
      DO 154 I=1,22
      DO 155 J=NOX,NODES
      IF(IBJNOD(I).NE.IANODB(J))GO TO 155
      IBJNOB(I)=J
      GO TO 154
  155 CONTINUE
  154 CONTINUE
      DO 156 I=1,6
      DO 157 J=NOX,NODES
      IF(MBLNOD(I).NE.IANODB(J))GO TO 157
      MBLNOB(I)=J
      GO TO 156
  157 CONTINUE
  156 CONTINUE
      DO 158 I=1,2
      DO 159 J=NOX,NODES
      IF(KBLNOD(I).NE.IANODB(J))GO TO 159
      KBLNOB(I)=J
      LBKNOB(I)=J
      GO TO 158
  159 CONTINUE
  158 CONTINUE
      DO 160 I=1,3
```

```
      DO 161 J=NOX,NODES
      IF(IBKNOD(I).NE.IANODB(J))GO TO 161
      IBKNOB(I)=J
      KRINOB(I)=J
      GO TO 160
  161 CONTINUE
  160 CONTINUE
      DO 621 I=1,5
      DO 622 J=NOX,NODES
      IF(MNATND(I).NE.IANODB(J))GO TO 622
      MNATNB(I)=J
      GO TO 621
  622 CONTINUE
  621 CONTINUE
      DO 623 I=1,4
      DO 624 J=NOX,NODES
      IF(LNATND(I).NE.IANODB(J))GO TO 624
      LNATNB(I)=J
      GO TO 623
  624 CONTINUE
  623 CONTINUE
      DO 625 I=1,2
      DO 626 J=NOX,NODES
      IF(KNATND(I).NE.IANODB(J))GO TO 626
      KNATNB(I)=J
      GO TO 625
  626 CONTINUE
  625 CONTINUE
      DO 627 I=1,12
      DO 628 J=NOX,NODES
      IF(INATND(I).NE.IANODB(J))GO TO 628
      INATNB(I)=J
      GO TO 627
  628 CONTINUE
  627 CONTINUE
      DO 629 I=1,280
      DO 630 J=NOX,NODES
      IF(NNATND(I).NE.IANODB(J))GO TO 630
      NNATNB(I)=J
      GO TO 629
  630 CONTINUE
  629 CONTINUE
      DO 631 I=1,280
      DO 632 J=NOX,NODES
      IF(NACEND(I).NE.IANODB(J))GO TO 632
      NACENB(I)=J
      GO TO 631
  632 CONTINUE
  631 CONTINUE
 1000 READ(5,53)IHOME
      ITER=0
      INDEX=INDEX+1
      DO 170 I=1,NODES
      IBNODB(I)=0
  170 LABENB(I)=9999.
      IANODB(1)=IHOME
      LABENB(1)=0.
      DO 180 I=1,18
      IXA=MMNOBE(I)
      IBNODB(IXA)=IHOME
  180 LABENB(IXA)=DISTMC(I,INDEX)
```

```
1100 ITER=ITER+1
     ITCH=0
     DO 182 I=1,22
     IXB=LBJNOB(I)
     DO 182 J=1,11
     IXC=MBJNOB(J)
     TOTAL=LABENB(IXC)+DISTML(J,I)
     IF(TOTAL.GE.LABENB(IXB))GO TO 182
     IBNODB(IXB)=IANODB(IXC)
     LABENB(IXB)=TOTAL
     ITCH=ITCH+1
 182 CONTINUE
     DO 184 I=1,30
     IXB=LLNOBE(I)
     DO 184 J=1,6
     IXC=MBLNOB(J)
     TOTAL=LABENB(IXC)+DMBLLL(J,I)
     IF(TOTAL.GE.LABENB(IXB))GO TO 184
     IBNODB(IXB)=IANODB(IXC)
     LABENB(IXB)=TOTAL
     ITCH=ITCH+1
 184 CONTINUE
     DO 702 I=1,11
     IXB=MBJNOB(I)
     DO 702 J=1,22
     IXC=LBJNOB(J)
     TOTAL=LABENB(IXC)+DISTML(I,J)
     IF(TOTAL.GE.LABENB(IXB))GO TO 702
     IBNODB(IXB)=IANODB(IXC)
     LABENB(IXB)=TOTAL
     ITCH=ITCH+1
 702 CONTINUE
     DO 704 I=1,6
     IXB=MBLNOB(I)
     DO 704 J=1,30
     IXC=LLNOBE(J)
     TOTAL=LABENB(IXC)+DMBLLL(I,J)
     IF(TOTAL.GE.LABENB(IXB))GO TO 704
     IBNODB(IXB)=IANODB(IXC)
     LABENB(IXB)=TOTAL
     ITCH=ITCH+1
 704 CONTINUE
     DO 186 I=1,2
     IXB=KBLNOB(I)
     DO 186 J=1,30
     IXC=LLNOBE(J)
     TOTAL=LABENB(IXC)+DKBLLL(I,J)
     IF(TOTAL.GE.LABENB(IXB))GO TO 186
     IBNODB(IXB)=IANODB(IXC)
     LABENB(IXB)=TOTAL
     ITCH=ITCH+1
 186 CONTINUE
     DO 192 I=1,22
     IXB=IBJNOB(I)
     DO 192 J=1,11
     IXC=MBJNOB(J)
     TOTAL=LABENB(IXC)+DISTMI(J,I)
     IF(TOTAL.GE.LABENB(IXB))GO TO 192
     IBNODB(IXB)=IANODB(IXC)
     LABENB(IXB)=TOTAL
     ITCH=ITCH+1
```

```
192 CONTINUE
    DO 194 I=1,22
    IXB=IBJNOB(I)
    DO 194 J=1,22
    IXC=LBJNOB(J)
    TOTAL=LABENB(IXC)+DISTLI(J,I)
    IF(TOTAL.GE.LABENB(IXB))GO TO 194
    IBNODB(IXB)=IANODB(IXC)
    LABENB(IXB)=TOTAL
    ITCH=ITCH+1
194 CONTINUE
    DO 188 I=1,8
    IXB=KBJNOB(I)
    DO 188 J=1,11
    IXC=MBJNOB(J)
    TOTAL=LABENB(IXC)+DISTMK(J,I)
    IF(TOTAL.GE.LABENB(IXB))GO TO 188
    IBNODB(IXB)=IANODB(IXC)
    LABENB(IXB)=TOTAL
    ITCH=ITCH+1
188 CONTINUE
    DO 190 I=1,8
    IXB=KBJNOB(I)
    DO 190 J=1,22
    IXC=LBJNOB(J)
    TOTAL=LABENB(IXC)+DISTLK(J,I)
    IF(TOTAL.GE.LABENB(IXB))GO TO 190
    IBNODB(IXB)=IANODB(IXC)
    LABENB(IXB)=TOTAL
    ITCH=ITCH+1
190 CONTINUE
    DO 202 I=1,3
    IXB=IBKNOB(I)
    DO 202 J=1,25
    IXC=IINOBE(J)
    TOTAL=LABENB(IXC)+DKBIII(I,J)
    IF(TOTAL.GE.LABENB(IXB))GO TO 202
    IBNODB(IXB)=IANODB(IXC)
    LABENB(IXB)=TOTAL
    ITCH=ITCH+1
202 CONTINUE
    DO 706 I=1,8
    IXB=KBJNOB(I)
    DO 706 J=1,22
    IXC=IBJNOB(J)
    TOTAL=LABENB(IXC)+DISTKI(I,J)
    IF(TOTAL.GE.LABENB(IXB))GO TO 706
    IBNODB(IXB)=IANODB(IXC)
    LABENB(IXB)=TOTAL
    ITCH=ITCH+1
706 CONTINUE
    DO 198 I=1,13
    IXB=KKNOBE(I)
    DO 198 J=1,2
    IXC=LBKNOB(J)
    TOTAL=LABENB(IXC)+DLBKKK(J,I)
    IF(TOTAL.GE.LABENB(IXB))GO TO 198
    IBNODB(IXB)=IANODB(IXC)
    LABENB(IXB)=TOTAL
    ITCH=ITCH+1
198 CONTINUE
```

```
      DO 708 I=1,25
      IXB=IINOBE(I)
      DO 708 J=1,3
      IXC=IBKNOB(J)
      TOTAL=LABENB(IXC)+DKBIII(J,I)
      IF(TOTAL.GE.LABENB(IXB))GO TO 708
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  708 CONTINUE
      DO 196 I=1,22
      IXB=IBJNOB(I)
      DO 196 J=1,8
      IXC=KBJNOB(J)
      TOTAL=LABENB(IXC)+DISTKI(J,I)
      IF(TOTAL.GE.LABENB(IXB))GO TO 196
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  196 CONTINUE
      DO 200 I=1,3
      IXB=IBKNOB(I)
      DO 200 J=1,13
      IXC=KKNOBE(J)
      TOTAL=LABENB(IXC)+DIBKKK(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 200
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  200 CONTINUE
      DO 710 I=1,13
      IXB=KKNOBE(I)
      DO 710 J=1,3
      IXC=IBKNOB(J)
      TOTAL=LABENB(IXC)+DIBKKK(J,I)
      IF(TOTAL.GE.LABENB(IXB))GO TO 710
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  710 CONTINUE
      DO 712 I=1,2
      IXB=LBKNOB(I)
      DO 712 J=1,13
      IXC=KKNOBE(J)
      TOTAL=LABENB(IXC)+DLBKKK(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 712
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  712 CONTINUE
      DO 714 I=1,30
      IXB=LLNOBE(I)
      DO 714 J=1,2
      IXC=KBLNOB(J)
      TOTAL=LABENB(IXC)+DKBLLL(J,I)
      IF(TOTAL.GE.LABENB(IXB))GO TO 714
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  714 CONTINUE
      DO 716 I=1,22
```

```
      IXB=LBJNOB(I)
      DO 716 J=1,8
      IXC=KBJNOB(J)
      TOTAL=LABENB(IXC)+DISTLK(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 716
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  716 CONTINUE
      DO 718 I=1,22
      IXB=LBJNOB(I)
      DO 718 J=1,22
      IXC=IBJNOB(J)
      TOTAL=LABENB(IXC)+DISTLI(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 718
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  718 CONTINUE
      DO 720 I=1,11
      IXB=MBJNOB(I)
      DO 720 J=1,22
      IXC=IBJNOB(J)
      TOTAL=LABENB(IXC)+DISTMI(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 720
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  720 CONTINUE
      DO 722 I=1,11
      IXB=MBJNOB(I)
      DO 722 J=1,8
      IXC=KBJNOB(J)
      TOTAL=LABENB(IXC)+DISTMK(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 722
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  722 CONTINUE
      DO 204 I=1,65
      IXB=I+1
      DO 204 J=1,30
      IXC=LLNOBE(J)
      TOTAL=LABENB(IXC)+DISTLC(J,I)
      IF(TOTAL.GE.LABENB(IXB))GO TO 204
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  204 CONTINUE
      DO 206 I=1,34
      IXB=I+66
      DO 206 J=1,13
      IXC=KKNOBE(J)
      TOTAL=LABENB(IXC)+DISTKC(J,I)
      IF(TOTAL.GE.LABENB(IXB))GO TO 206
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  206 CONTINUE
      DO 208 I=1,98
      IXB=I+100
```

```
      DO 208 J=1,25
      IXC=IINOBE(J)
      TOTAL=LABENB(IXC)+DISTIC(J,I)
      IF(TOTAL.GE.LABENB(IXB))GO TO 208
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  208 CONTINUE
      DO 640 I=1,5
      IXB=MNATNB(I)
      DO 640 J=1,18
      IXC=MMNOBE(J)
      TOTAL=LABENB(IXC)+DISTMN(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 640
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  640 CONTINUE
      DO 642 I=1,4
      IXB=LNATNB(I)
      DO 642 J=1,30
      IXC=LLNOBE(J)
      TOTAL=LABENB(IXC)+DISTLN(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 642
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  642 CONTINUE
      DO 644 I=1,2
      IXB=KNATNB(I)
      DO 644 J=1,13
      IXC=KKNOBE(J)
      TOTAL=LABENB(IXC)+DISTKN(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 644
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  644 CONTINUE
      DO 646 I=1,12
      IXB=INATNB(I)
      DO 646 J=1,25
      IXC=IINOBE(J)
      TOTAL=LABENB(IXC)+DISTIN(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 646
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  646 CONTINUE
      DO 650 I=1,280
      IXC=NNATNB(I)
      IXB=NACENB(I)
      TOTAL=LABENB(IXC)+DISTNC(I)
      IF(TOTAL.GE.LABENB(IXB))GO TO 650
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
  650 CONTINUE
  809 ITCHY=0
      DO 728 I=1,18
      IXB=MMNOBE(I)
      DO 728 J=1,18
```

```
      IXC=MMNOBE(J)
      TOTAL=LABENB(IXC)+DMBJMJ(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 728
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
      ITCHY=ITCHY+1
  728 CONTINUE
      IF(ITCHY.NE.0)GO TO 809
  802 ITCHY=0
      DO 730 I=1,22
      IXB=LBJNOB(I)
      DO 730 J=1,22
      IXC=LBJNOB(J)
      TOTAL=LABENB(IXC)+DLBJLJ(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 730
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
      ITCHY=ITCHY+1
  730 CONTINUE
      IF(ITCHY.NE.0)GO TO 802
  805 ITCHY=0
      DO 736 I=1,8
      IXB=KBJNOB(I)
      DO 736 J=1,8
      IXC=KBJNOB(J)
      TOTAL=LABENB(IXC)+DKBJKJ(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 736
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
      ITCHY=ITCHY+1
  736 CONTINUE
      IF(ITCHY.NE.0)GO TO 805
  804 ITCHY=0
      DO 742 I=1,22
      IXB=IBJNOB(I)
      DO 742 J=1,22
      IXC=IBJNOB(J)
      TOTAL=LABENB(IXC)+DIBJIJ(I,J)
      IF(TOTAL.GE.LABENB(IXB))GO TO 742
      IBNODB(IXB)=IANODB(IXC)
      LABENB(IXB)=TOTAL
      ITCH=ITCH+1
      ITCHY=ITCHY+1
  742 CONTINUE
      IF(ITCHY.NE.0)GO TO 804
      IF(ITCH.NE.0)GO TO 1100
      DO 800 K=1,NODES
  800 LENGTH(K)=LABENB(K)
      WRITE(6,270)IHOME,ITER
  270 FORMAT(1H1,22H THE STARTING NODE IS ,I5,5X,11HITERATIONS=,I3)
      WRITE(6,290)(IANODB(I),IBNODB(I),LABENB(I),I=1,NODES)
  290 FORMAT(7(2X,2I5,F6.0))
      CALL PATHS
      GO TO 1000
  300 STOP
      END
$IBFTC SUBPI    SMAP
      SUBROUTINE PATHS
```

```
      DIMENSION IANODB(360),IBNODB(360),LABENB(360),IBAKND(100)
      COMMON IHOME,NODES,IANODB,IBNODB,LABENB,NIX,NOX,KIX
      REAL LABENB,IBAKDT
      WRITE(6,460)IHOME
  460 FORMAT(1H0,6X,16HTHE HOME NODE IS,I5,3X,21HTHE MINIMUM PATHS ARE/)
      DO 500 I=2,KIX
      IBAKDT=LABENB(I)
      INCRMT=I
      DO 520 K=1,100
      KOUNT=K
      IBAKND(K)=IANODB(INCRMT)
      IF(IBNODB(INCRMT).EQ.IHOME)GO TO 550
      DO 530 L=NOX,NODES
      IF(IBNODB(INCRMT).NE.IANODB(L))GO TO 530
      INCRMT=L
      GO TO 520
  530 CONTINUE
  520 CONTINUE
  550 KOUNT=KOUNT+1
      IBAKND(KOUNT)=IHOME
      WRITE(6,560)IBAKDT,(IBAKND(M),M=1,KOUNT)
  560 FORMAT(1H ,3X,F5.0,3X,20I5)
  500 CONTINUE
      RETURN
      END
$DATA
```

VITA

VITA

Walter Charles Vodrazka was born August 27, 1933 in Clinton, New Jersey. His primary and secondary education were received in New York City where he was graduated from St. Ann's Academy in 1951.

He received the Bachelor of Civil Engineering degree from Manhattan College in 1955 and the Master of Science degree from Mississippi State University in 1962.

From 1955 to 1956 he was employed by the U. S. Army Corps of Engineers and from 1956 to 1957 by Seelye, Stevenson, Value, and Knecht, Consulting Engineers.

In 1957, he joined the staff of Mississippi State University as an Instructor and in 1962 was promoted to Assistant Professor of Civil Engineering. He took a leave of absence from this position in 1963 to undertake additional graduate study at Purdue University.

He is a registered Professional Engineer in the States of Indiana and Mississippi. He is a member of the American Society of Civil Engineers, an associate member of the Operations Research Society of America, the Highway Research Board, and of Sigma Xi research honorary, and a student member of the Institute of Traffic Engineers.